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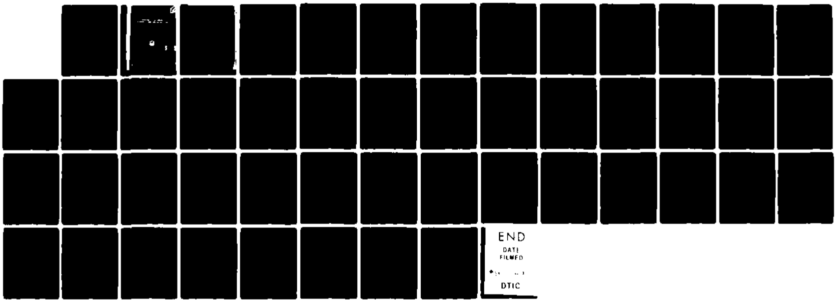

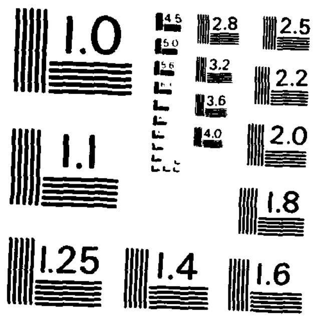

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EVALUATION OF A GN_2 POWERED, MECHANICALLY LINKED DUAL EJECTOR SYSTEM (U)

(Article UNCLASSIFIED)

by

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ABSTRACT. This report contains a description and evaluation of a Naval Weapons Center (NWC) designed dual ejector system that is cold gas (GN_2) powered and uses hydraulic fluid as a media for ejection stroke extension. The report describes the construction of the system, tests performed and data obtained. The system has two identical ejector housing assemblies, each containing hydraulic fluid, a fluid displacing piston and telescoping pistons for ejection stroke. The GN_2 pressure housing assembly has a piston for power output. The fluid displacing pistons and the GN_2 power piston are mechanically linked to provide positive dependency in movement. For parallel ejection, ejector extension is equal with the ejection force proportionally equilibrating the reacting forces encountered by the individual ejector assemblies. This proportional force distribution between ejector assemblies during parallel or pitch angle ejection requires no sensors or regulators. Using hydraulic fluid as a media for ejector extension allows control of the individual telescoping piston length of travel if other than positive parallel ejection is desired. By manually controlling the amount of fluid available for extension in either ejector assembly, variations in stroke length of the two ejector assemblies telescoping pistons can create stores pitch angle change or angular rate inducement. The ejection force is all on one of the two ejector assemblies for the angular rate ejection mode.

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INTRODUCTION

This report provides descriptive and initial test data for a dual ejector system which is cold gas (GN_2) powered and enables selected pitch attitude or pitch rate of aircraft store ejection, regardless of external perturbances during the ejection sequence. This design will consistently eject a store into a safe and predictable trajectory.

Ejector systems presently in use cannot react to unknown infinite variations in forces and moments acting upon the store during the ejection cycle, particularly at supersonic speeds. As the requirements for aircraft and store delivery speeds increase, the nonuniform forces acting upon the store become more critical to predictable safe store separation. Without consistently predictable launch of the store with minimal perturbances, a large amount of delivery error is inevitable. There is evidence that these forces and moments acting upon the store during the launch cycle constitute the largest single source of bomb dispersion. These launch dispersions are referred to as mal-launch dispersion and are defined as the variation in forces acting upon the store during the entire ejection cycle until the bomb is clear of the nonuniform flow field surrounding the launch platform.

It is estimated that mal-launch dispersion contributes more delivery error than the combined effects of aim error and in-flight ballistic dispersion error (caused by imperfections introduced in the manufacturing and handling of a store, such as bent fins, etc.) during a typical supersonic ($\sim$ 800 kts) store ejection from an aircraft[1]. Under this launch condition, it is estimated the aim error for computer aided delivery systems contributes an average of 10 mils CEP (circular probable error) of dispersion, in-flight ballistic dispersion contributes 4 mils CEP and mal-launch contributes up to 20 mils CEP. If mal-launch dispersion error can be reduced to a figure comparable to the 10 mil aim error, the single bomb hit probability can be improved from approximately 0.31 to 0.59, with a real effectiveness (hit probability) improvement of 90%.

The dual ejector system described herein, by enabling a selected parallel, pitch attitude change or pitch angular rate of ejection, will guarantee consistently safe store separation from the aircraft with no launch envelope limitations. Improved aiming devices being incorporated in currently operational aircraft will tend to reduce aim error toward the 4 mil CEP magnitude of in-flight dispersion. If both aim error and mal-launch dispersion can be reduced to this magnitude, real effectiveness (single-hit probability) improves to <u>0.89</u> - a "whopping" overall accuracy improvement of 187%.

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[1] Maestri, Raymond R., and Schindel, Leon H. (U) <u>Self-Compensating Store Ejection</u>. NOLTR 74-3, Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland, 5 February 1974.

The capability to vary the ejection force is a highly desirable feature of a stores ejection system. Variance of ejection force, relative to stores weight, enables achievement of desired end of stroke velocity which is important due to inertial loads that are imposed by the delivery aircraft. Variable ejection force is possible with an ejection system powered by a cold gas pressure source. The use of a noncontaminating power source for ejection reduces cleaning maintenance to a bare minimum. As an example, there has been no maintenance required on the dual ejector system used for the tests described in this report after 325 ejection cycles. The use of hydraulics in a closed system (i.e. no lines, pumps, fittings, reservoirs or restrictions), pressurized only during ejection stroke duration, and with designed sealing capability, should eliminate the objectionable leakage characteristics of most present hydraulic systems. Experience has shown that the use of the Greene Tweed (GT) T-seals in the hydraulic and pneumatic systems should reduce the maintenance to almost zero. The use of standard O-ring seals is not recommended for this application. A list of current aircraft which presently use the GT seals is shown in appendix A. There have been literally no failures of this type of seal in the applications since their introduction.

This is a modular system and positive parallel ejection is the systems primary function. The pitch attitude control, pitch rate control, and variable power control with pressurized GN_2 are additional features that can be incorporated into an ejector system design, if requirements dictate. The use of a pyrotechnic cartridge activated device (CAD) in place of the cold gas source is optional with this system, but is not recommended due to maintenance requirements.

Cold gas pressure settings ranging from 1000 to 3000 psig were tested to determine efficiencies at the selected pressures. Input pressure, accelerations, applied force and distribution of pressure were measured and recorded. A Mk 82 bomb (actual weight - 489 lb) with a conical tail fin was used for these tests. The nose cone was grooved to allow a steel cable to apply external force, simulating induced moments of 16,000 or 32,000 in.-lbs on the store. Parallel ejection with, and without, externally applied force was tested. Store pitch angle and pitch rate establishment, with and without loads, was tested.

DESCRIPTION

TECHNIQUE COMPARISON

Current bomb rack ejector systems are powered by hot gas with single or dual ejector piston systems. Propellant cartridges or CADs generate expanding hot gasses which extend the pistons, and provide ejector force. Two ejector pistons provide for better distribution of the available ejection forces on the weapon body. Since the stores to be suspended and released vary considerably in geometric shape and weight, their respective center of gravities may vary along a longitudinal axis relative to the ejector pistons. While suspended on the aircraft during flight, the aerodynamic flow field about the aircraft and store induce external forces and moments on the weapon which may cause pitch, yaw and rotation of the weapon during ejection. A brief comparison of a gas linked and mechanically linked dual ejection system is provided in the following, together with the advantages and disadvantages of each system, respectively. For discussion purposes, it is assumed that both systems are CAD powered.

GAS LINKED SYSTEM

A gas linked ejector system typical of those currently in service, is shown in Figure 1. A breech assembly with 2 cartridges is connected to each telescoping piston ejector assembly by a conduit. Since there is no physical connection between the telescoping pistons, each piston functions independently of the other. In order to compensate for CG tolerance and aerodynamic forces and moments (if known), orifices can be inserted into the conduits to meter or change the flow of gases causing an increase or decrease in the forces required to overcome these external resistances. The variability of the external resistances is likely to create an inconsistent, nonparallel ejection stroke due to the force application at the point of least resistance.

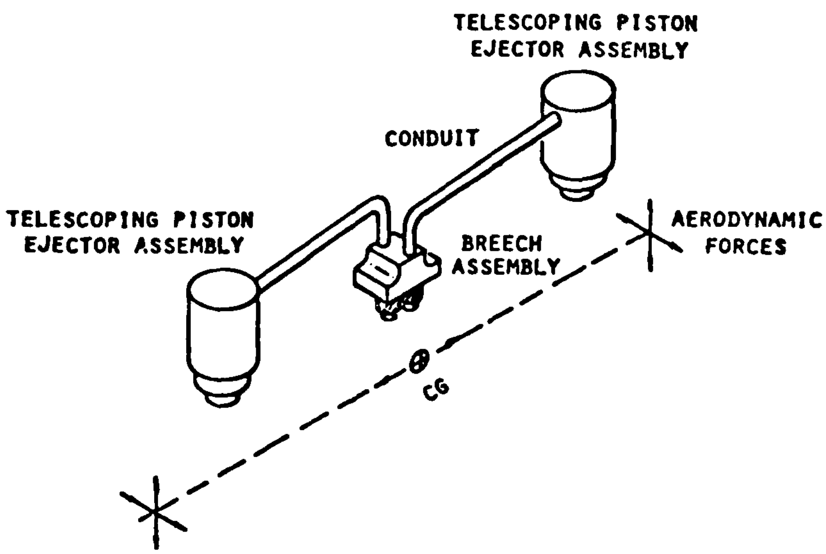


Figure 1. Gas Linked Ejector System.

MECHANICALLY LINKED SYSTEM

A mechanically linked ejector system schematic is shown in Figure 2. The breech assembly contains two cartridges and a power piston which is mechanically linked to the two ejector assemblies. This linking results in dependent ejector strokes in that one piston assembly cannot extend without the other. The force application occurs at the point of greatest resistance, and both pistons extending together give repeatedly parallel consistent stores ejection. No adjustments are required to overcome changes in CG and aerodynamic forces.

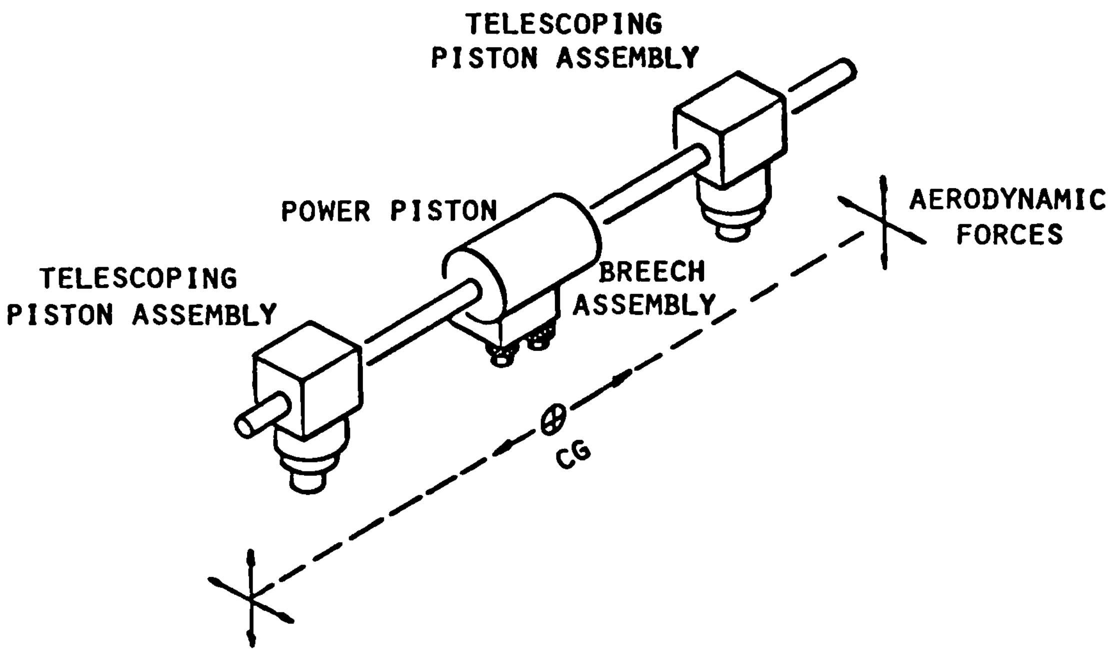


Figure 2. Mechanically Linked Ejector System.

Mechanically linked systems are unaffected by changes in weapon CG and aerodynamic flow field forces. Mechanical dependency automatically applies the ejection forces to the point of greatest resistance, while gas independent systems apply forces to the point of least resistance, thereby compounding a possible undesirable separation condition. Mechanically linked ejectors can maintain store pitch control automatically over the range of the release envelope, while gas systems require an adjustible orifice or metering system which is usually set prior to launch for a specific set of release conditions.

Gas ejector systems have the advantage over mechanical systems in that they are usually smaller and lighter in weight. This brief comparison of the two ejector systems show that the mechanically linked dependent ejector systems have several advantages over the gas linked systems.

NWC DESIGNED DUAL EJECTOR SYSTEM

The NWC designed dual ejector system assembly (Figure 3) consists of two ejector assemblies (Figure 3, Item 1), a gas pressurized power system (Item 2), connecting linkages (Item 3), pressure sensors and control valves and a release unit (Item 4). The connecting linkage mechanically connects the gas power system output piston and both input pistons of the ejector assemblies, so that each of the three pistons become movement (ejection stroke) dependent of the others.

Ejector Assembly

Each ejector assembly (Figure 4) consists of a housing (Figure 4, Item 1), an input piston (Item 2), a hydraulic oil chamber (Item 3), a floating piston and spring (Item 4), an adjustable stop (Item 5), a telescoping piston (Item 6) and a return spring and weapon contact adjustment assembly (Item 7). The floating piston, spring and adjustable stop is part of an adjustment device for varying the stroke length. The unit is also equipped with a pressure transducer (Item 8) for recording the pressure during the ejection stroke.

Ejector Stroke Adjustment Device

Each ejector assembly is equipped with an adjustment device for reducing the telescoping piston ejector stroke length. The stroke length control feature is made possible by a separate piston and spring (Figure 4, Item 4) and an adjustable stop (Item 5) which can be positioned to effect a change in the volume of the hydraulic oil chamber (Item 3). During ejection, oil is displaced within the chamber and the adjustable stop controls the volume of oil which is diverted into a closed bypass in the housing. The preselected amount of oil diverted into the bypass detracts from the total volume of oil available to extend the ejector

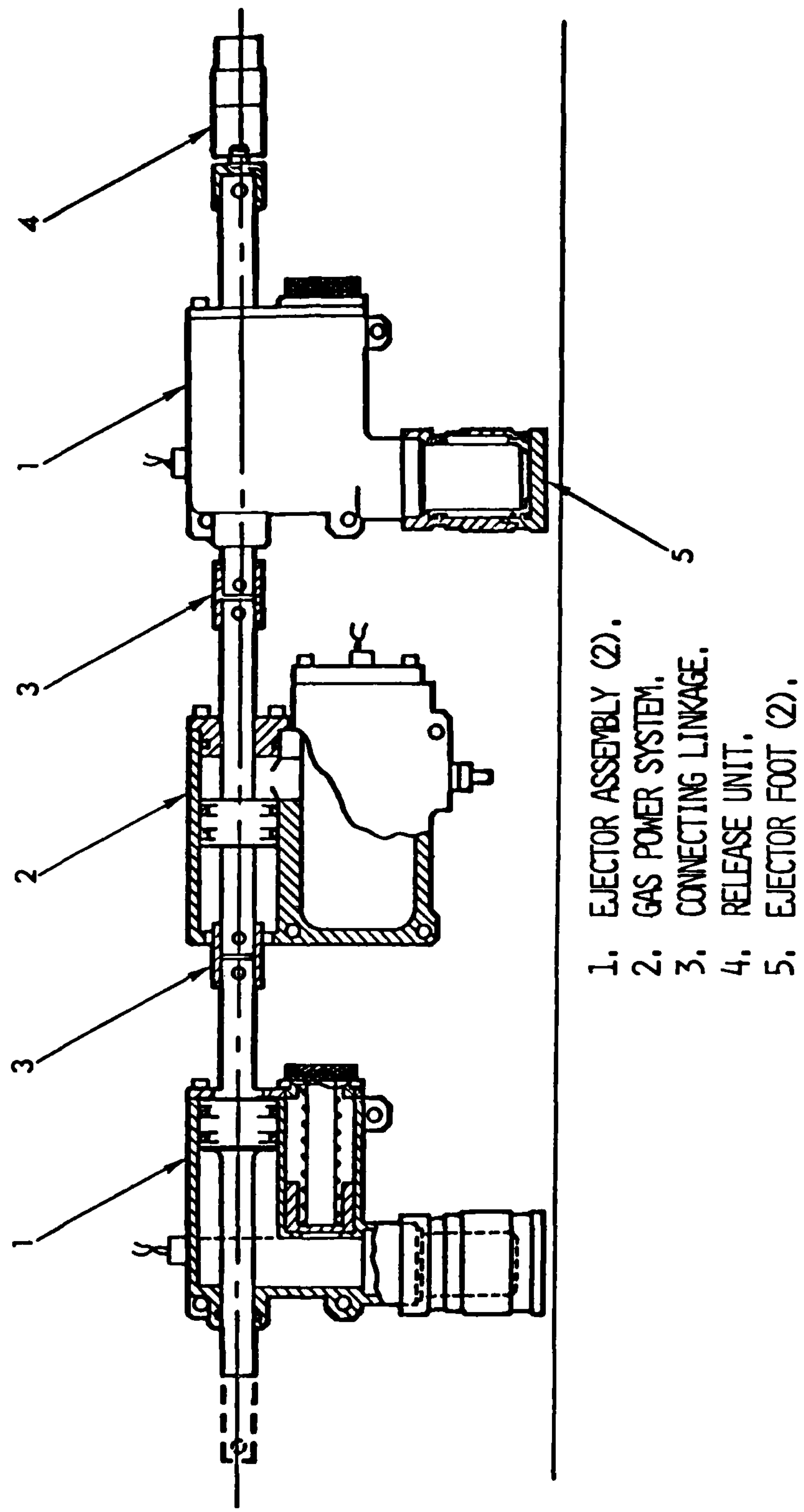


Figure 3. Dual Ejector System.

pistons, thereby shortening the ejector foot stroke to the selected length. This results in one ejector piston ejecting the nose (or tail) of the store downward during the initial ejection sequence while the other ejector piston pushes the opposite end of the store downward after a delay, with both pistons reaching their selected stroke limit at the same time. The adjustment device for either (or both) of the ejector assemblies can be adjusted for any ejection stroke limit between zero and 6.0 inches on the test model, as required.

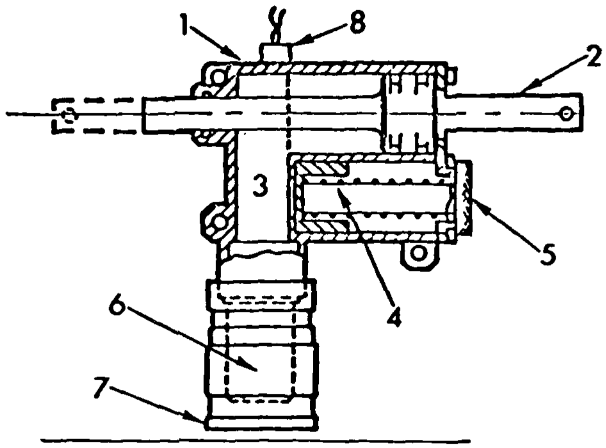


Figure 4. Ejector Assembly.

The cold gas power system (Figure 5) consists of a housing (Figure 5, Item 1), a power output piston (Item 2), a pressure chamber (Item 3), a filler valve (Item 4) and a pressure sensor (Item 5). The gas chamber was pressurized from a pre-pressurized bottle system during this evaluation.

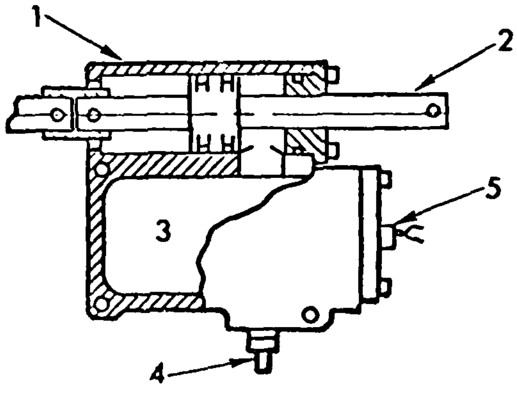


Figure 5. Gas Power System.

TESTING

TEST OBJECTIVES

Testing of the dual ejector system is to evaluate the following:

a) Efficiency of Ejection - The effect on system performance with variations in GN_2 ejection pressures.

b) Ejection Force Distribution - The inherent design characteristics of dependent dual ejection which dictate the ejection forces to be applied proportionally to the points of encountered resistance. The effect on force distribution with variations in ejection stroke length.

c) Attitude Change - The ability to induce or correct store pitch attitude by variations in ejector stroke length.

d) Externally Applied Force - The ability of the dual ejector system to balance externally applied forces and CG placements.

TEST SET-UP

The dual ejector system test set-up consisted of a 10,000 psi GN_2 cart attached to a pneumatic control panel for control of release and ejection pressures. The release pressure was set and then held constant for every test while the ejection pressure was incremented as required to meet the test plan. Release of the weapon was controlled through a basic fire control panel used for functioning standard bomb ejector cartridge systems.

A cable arrangement was provided which applied a downward force on the nose of a weapon to simulate an externally applied force, inducing a nose down rotation of the weapon during release (See Figure 6). The amount of cable force was controlled by means of a piston rod in a pneumatic cylinder, 8 feet in length, attached to the ends of the cable. The pounds force/pressure (psi) is shown graphically in Appendix A on Figure A-1. The cylinder was attached to a load cell to measure the applied load during ejection.

The dual ejector system was mounted to a steel frame over an ejection pit. The ejector system had 3 pressure transducers, one for the GN_2 chamber and one on each hydraulic ejector assembly. The Mk 82 bomb had accelerometers mounted on the bomb, forward and aft of the ejectors, and an equal distance from the center of the two ejectors. The store suspension mechanism and the power detent were made from a NADC lock-on coupling device (Figure 7). For test purposes, the availability of the NADC coupler precluded the need to design a new hood/lug device, or integrate an existing hook system. A linkage was built to operate the power

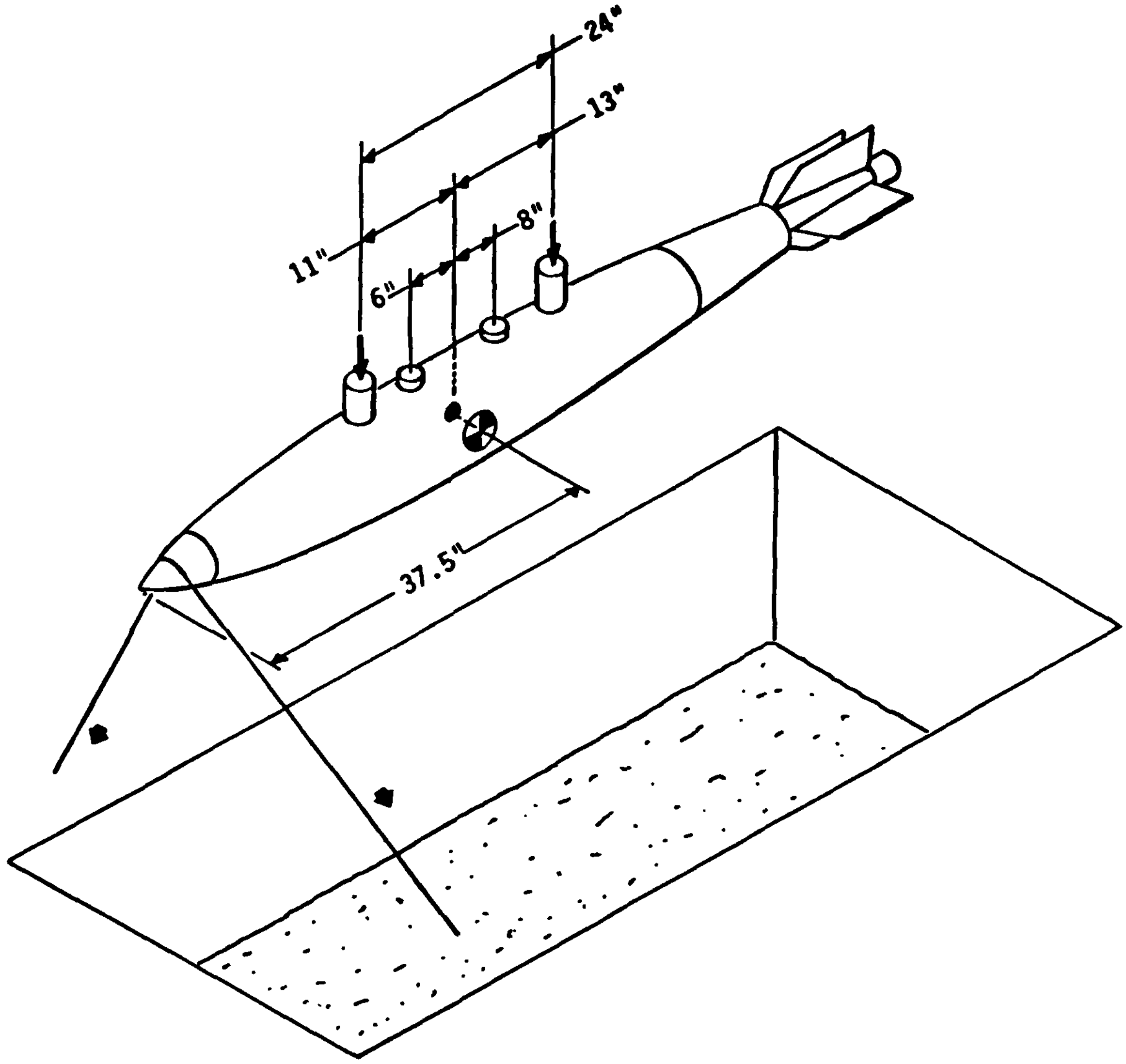


Figure 6. Mk 82 Bomb Ejection Test Set-up for Application of External Force.

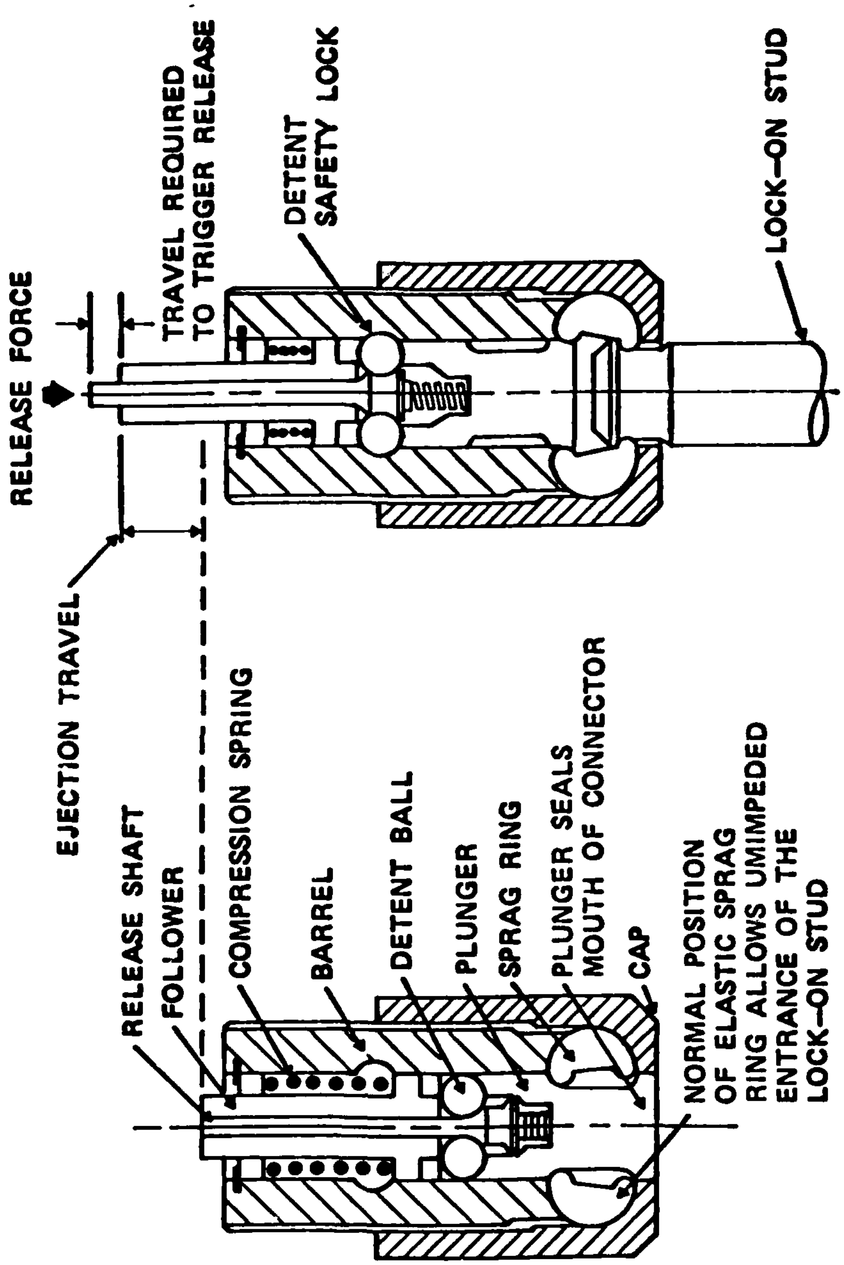


Figure 7. NADC Lock-On Coupling.

detent and weapon release couplers simultaneously. A small piston assembly was attached to the linkage and GN_2 pressure was used to actuate the mechanism. The release pressure was contained in a small pressure bottle, independent of the ejection pressure chamber, and was routed to the release piston via a solenoid valve. The firing pulse from the fire control panel actuated the solenoid valve.

TEST DATA

A 14 channel magnetic tape recorder was used to record the timing, hydraulic and GN_2 pressures, accelerations and load cell signals. The recorded data was later computer processed and reproduced. Examples of these data and results presented herein illustrate the functional capabilities of the dual ejector system.

Ejection Tests With No Applied External Force

Table I lists tests conducted without externally applied forces which are discussed in this report. Appendix A contains a complete listing of the tests performed. Data from 2 or 3 pressure ranges will be presented for comparison of performance parameters.

TABLE I. Ejection Test Conditions With No Externally Applied Force.

SERIES NO.	TEST NO.	EJECTOR STROKE (in.) FWD	AFT	GN_2 PRESSURE (psig)	EXTERNAL FORCE (lbs)
1	9	6.0	6.0	3000	0
2	9	6.0	4.5	3000	0
3	3	6.0	3.0	3000	0

A graph of the approximate time of ejection vs variations in the operating GN_2 pressures, using the Mk 82 bomb, is shown in Figure 8. A family of curves could be generated for various weight stores. Figure 9 shows characteristic pressure curves of the pressurized gas (GN_2) within the power system during ejection for various pressures. These pressure curves are typical regardless of the stroke settings and the applied external loads. As the power piston displaces within the housing, the pressure varies by the relationship $P_1V_1=P_2V_2$. No flow of GN_2 through conduits is required for functioning of the ejector pistons. Simple volumetric expansion from 65 to 75 in^3 is all that occurs.

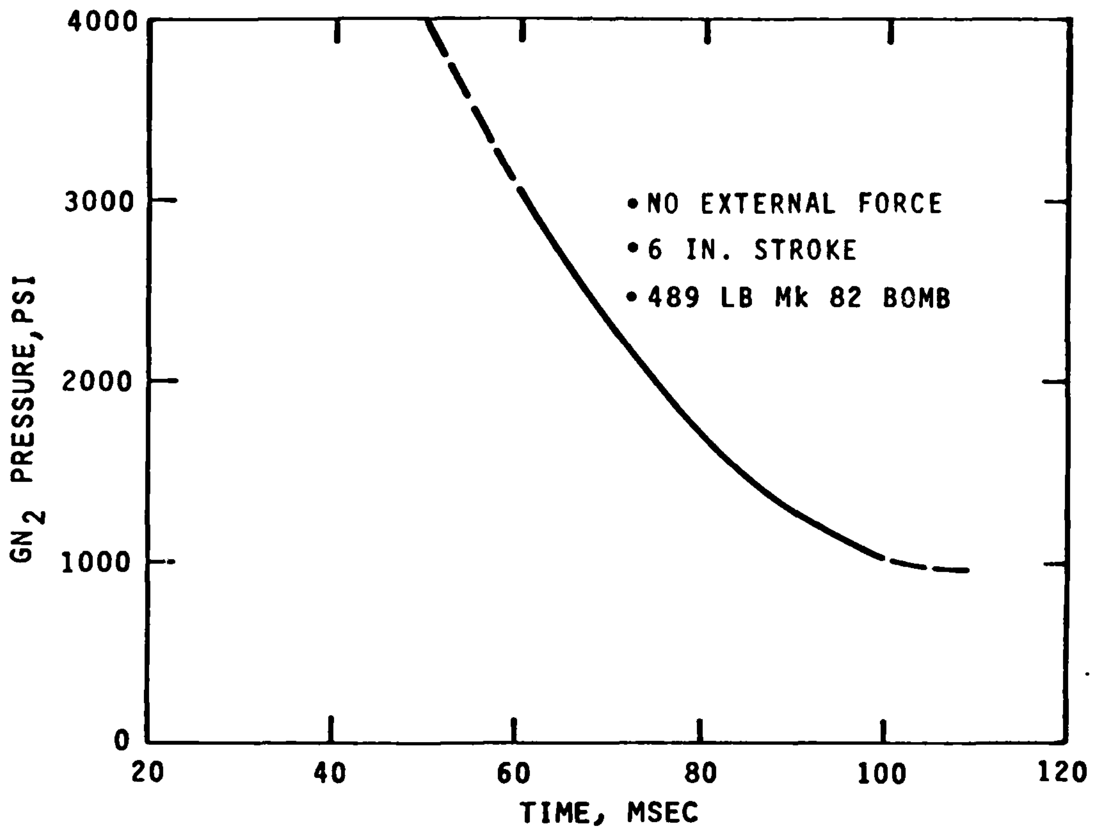


Figure 8. Stroke Time vs Pressure

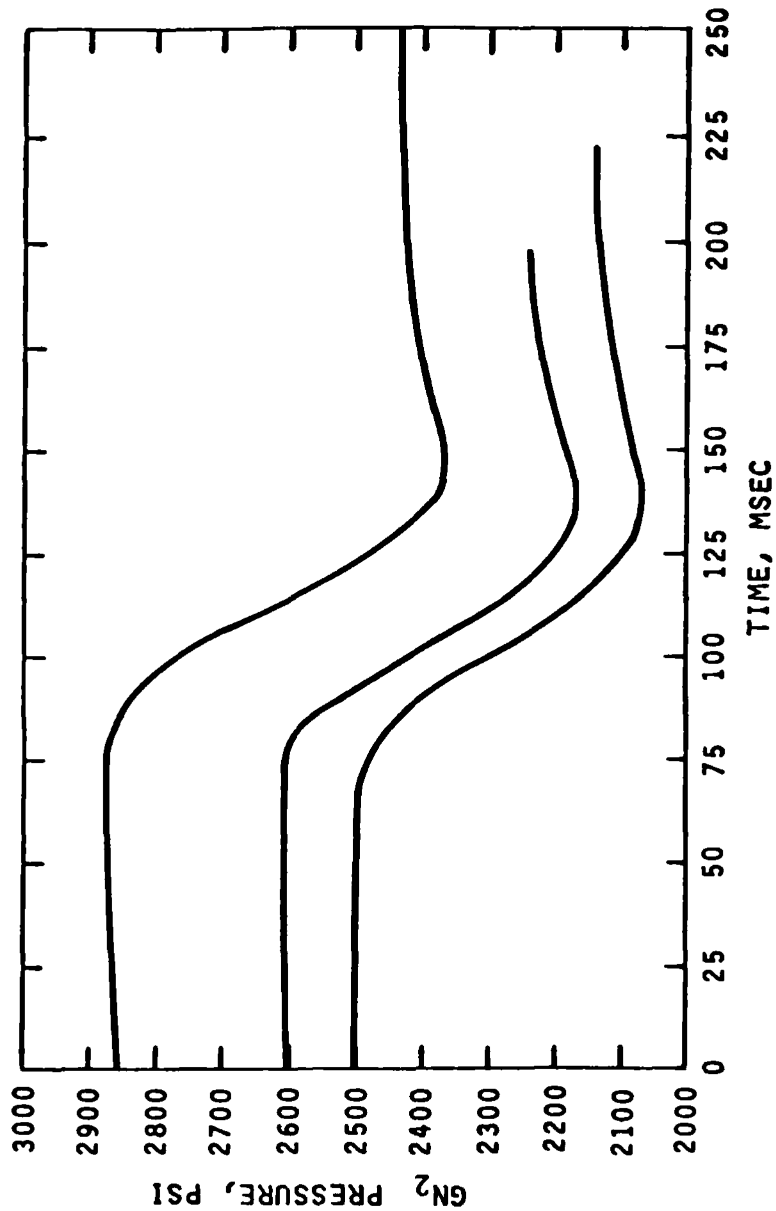


Figure 9. Characteristic Gas (GN_2) Pressures vs Time (During Ejection).

The slope of the curve is a function of the initial volume of the GN_2 chamber. A larger initial volume would give a better performance curve, since the pressure would decrease very little throughout the ejection stroke. This indicates the availability of nearly as much pressure at the end of the ejection stroke as at the beginning of the stroke. The losses within the ejector system were estimated to be a function of the hydraulic and pneumatic seals and the ejector piston return springs. Prior to ejection, the seals in the hydraulic units are at zero pressure until the load is applied. The static friction of the seals and the spring loads of the return sleeve assemblies must be overcome before the ejectors can move. The initial static load of the pneumatic seals is a significant variable which increases as the pressure increases. Since the pneumatic system is under pressure prior to ejection, this static force could be several hundred pounds. Once the system begins to function, this force is reduced to approximately one-third the initial value. In general, the static friction (under pressure) is greater than the running friction after the system begins the ejection sequence by a factor of 3. An indication of the losses was determined by measuring the pressures within the hydraulic assemblies and comparing these with the gas (GN_2) pressure. The operating efficiency of the ejector system was then calculated from the formula:

$$EFF = (PSI_{oil} \div PSI_{GN_2}) \times 100$$

This efficiency curve is graphically presented in Figure 10 and appears to approach an upper limit of 85 to 90%. This curve is for ambient conditions; additional testing will be required to determine the efficiency as a function of temperature.

Parallel Ejection

To obtain parallel ejection, the pressure forces must be distributed, as required, to maintain a stable store attitude during the ejection stroke. The total force available for ejection is the sum of the forces at each ejector piston. The ability to accomplish this function automatically, without sensors or regulators, is inherent in the design of positive displacement. Figure 11 shows the distribution of pressure between each ejector piston assembly during ejection and the total pressure summation curve. This total (sum of) pressure curve for this ejector system is represented by the formula:

$$(P_f + P_a) = \text{Pressure } (GN_2) \times \%\ \text{Efficiency}$$

Where:

P_f = Forward ejector pressure

P_a = Aft ejector pressure

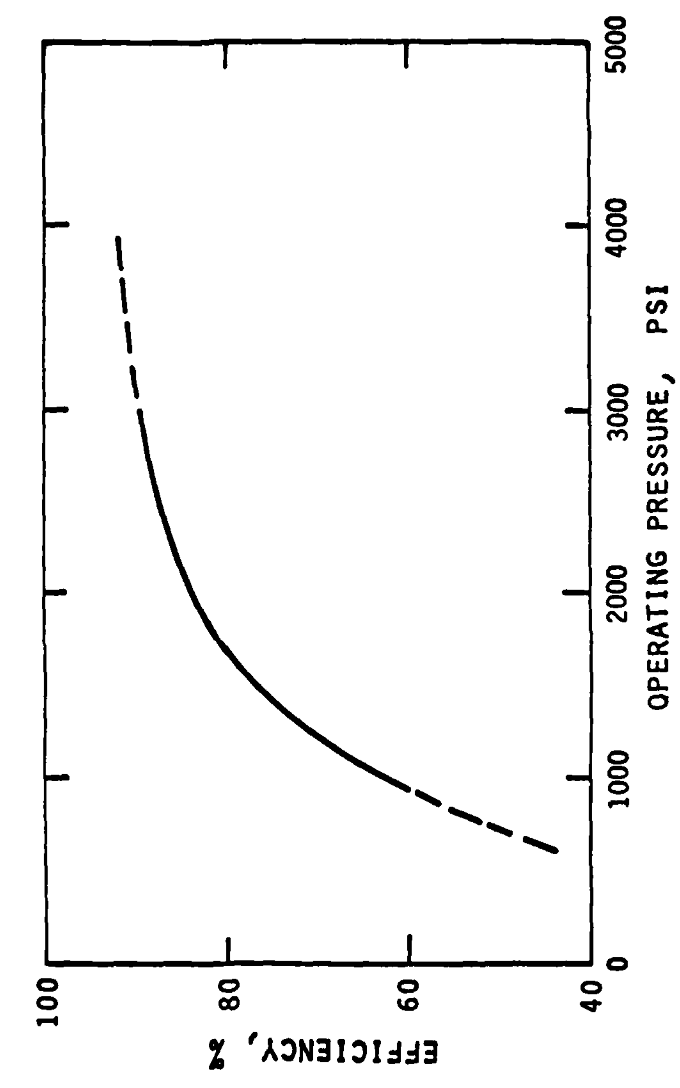


Figure 10. Ejector Gas (GN_2) Pressure Operating Efficiency.

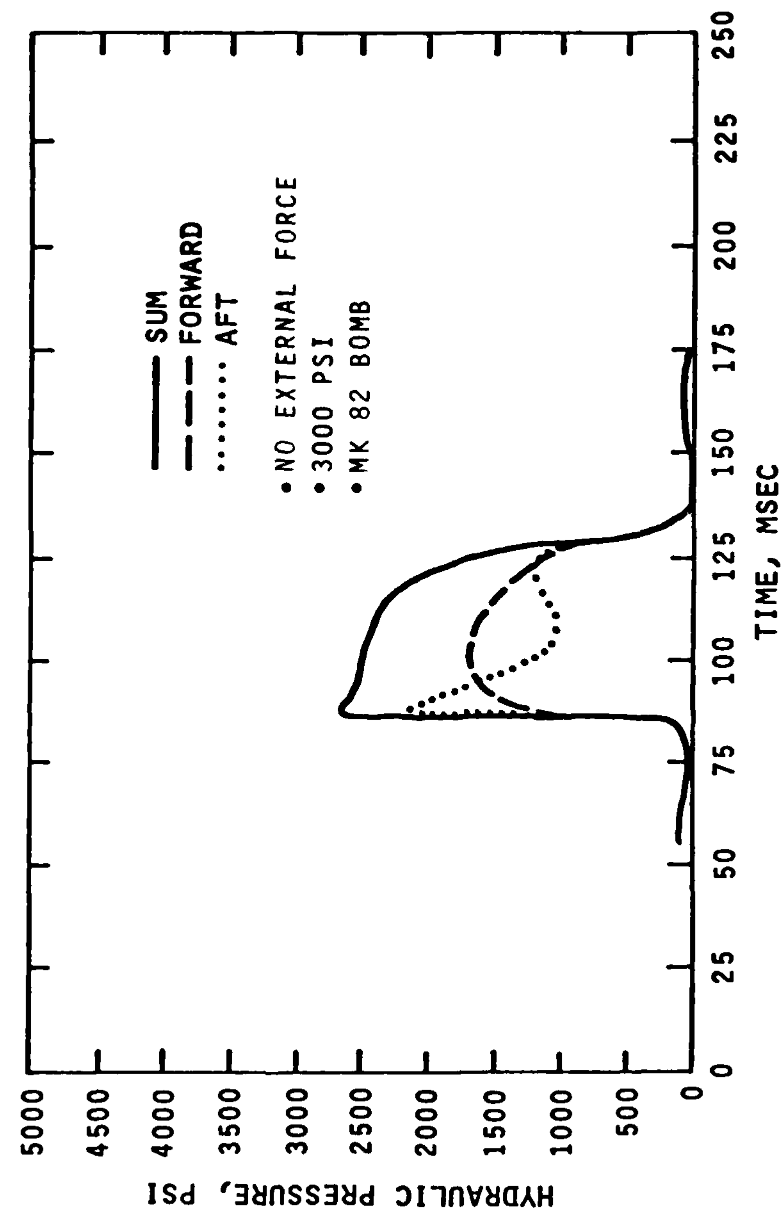


Figure 11. Ejector Piston Distribution and Summation of Pressures - 6/6 In. Strokes.

The curves reflect what is taking place internally during ejection. This distribution of pressure indicates the actual distribution of ejector forces on the store during the ejection cycle. The actual force application on the store is shown on Figure 12 and takes into account the area of the ejector pistons as a function of stroke length. The curve is the total force being applied by the ejector system to the store. Figure 12 shows the force is largest during the first piston extension, or the one with the largest area. At the time the smaller piston starts to extend, the area has been reduced approximately 50% and the force applied to the store is proportionately reduced. During the last 0.5 in of travel of the input piston (Figure 4, Item 2) this piston impacts a snubbing device and the ejection force drops to zero which is reflected in the force application curve of Figure 12. A small adjustment of this snubber can extend the power stroke further, but the additional amount of force being applied at this point is relatively small.

Non-Parallel Ejection

For test simplicity, only two adjustments were used for non-parallel ejection tests. The second (smaller) piston extension of 3.0 inches was divided into two increments enabling the stroke of the aft piston assembly to be reduced by 1.5 or 3.0 inches. With this arrangement, the full 6.0 inch ejection stroke of the aft piston could be reduced allowing the forward piston to reach its fully (6.0 inch) extended position while allowing the aft piston to extend only to 4.5 or 3.0 inches. (Both the forward and aft pistons, on test model, were fully adjustable for any stroke length of zero to 6.0 in.).

A series of tests were performed to evaluate the functions with one of the piston stroke lengths extending to only 4.5 or 3.0 inches. Figure 13 shows pressures within the ejector assemblies with 1.5 inches of stroke reduction induced in the aft piston (limiting the aft piston to a 4.5 inch stroke). It is noted that all of the pressure is being applied to the forward piston during the initial stroke (while the enlarged aft piston chamber is filling with oil). A short time later, the pressure in the aft assembly rapidly increases while the forward piston pressure is decreasing. At one point, the pressures are equal; eventually, the system is snubbed with both pressures dropping to zero at the end of the strokes. This induced stroke change causes an initial downward ejection of the nose of the store by the first piston, inducing a pitch angular rate until the second piston begins to apply force. The force of the second piston dampens the pitch rate, stabilizing the store at the selected pitch angle, and continues to maintain this attitude throughout the remainder of the stroke. This is a sure method of maintaining a fixed angle in the store attitude as a means of meeting a prescribed launch requirement, regardless of nonuniform external forces acting upon the store.

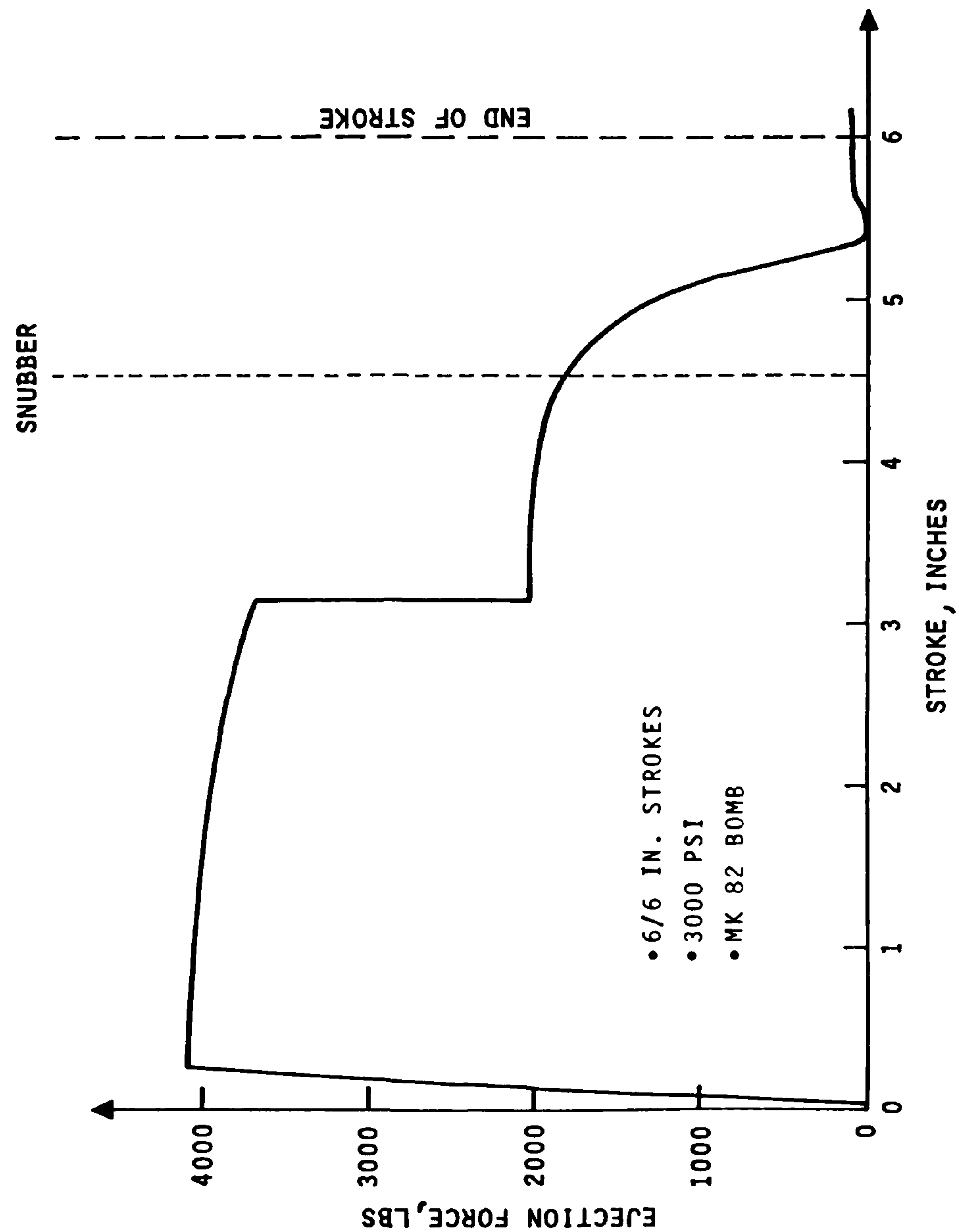


Figure 12. Force Application on Store During Ejection.

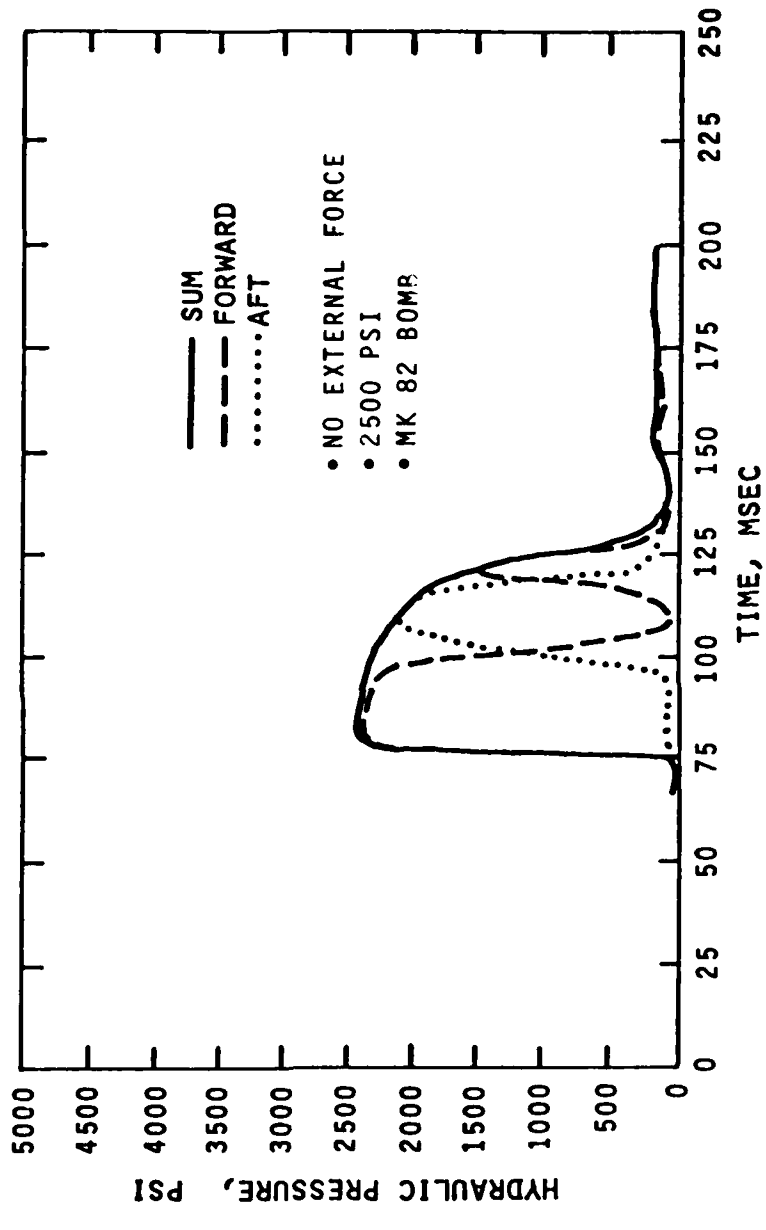


Figure 13. Forward and Aft Ejector Pressure Summation - 6/4.5 In. Strokes.

A 3.0 inch aft piston stroke reduction was induced and evaluated to determine the effect on store ejection. Figure 14 shows the pressure curves of the hydraulic assemblies with this induced ejection stroke change. It should be noted that the aft piston does not receive any pressure throughout the ejection cycle. Only the forward piston was applying ejection force inducing a pitch angular rate throughout the ejection cycle. The actual pressure curve of Figure 14 (6 in./3 in. stroke) is the same as the sum of pressures for a 6 in./6 in. or a 6 in./4.5 in. stroke (as shown on Figures 11 and 13, respectively) except all the pressure is applied to one piston.

Acceleration and Velocity During Ejection

The acceleration and velocity curves of the Mk 82 bomb at various ejection pressures are shown on Figures 15 and 16, respectively. These curves represent a 6 in./6 in. parallel ejection stroke. The velocity curves are integrations of the recorded acceleration of the forward and aft accelerometers on the bomb. Additional acceleration and velocity data for the 3000 psi ejection tests (without externally applied loads) are contained in Appendix B, Figures B-1, B-2 and B-3.

Ejection Tests With Applied External Force

Table II is a list of the tests in this report with force applied externally to the Mk 82 bomb:

TABLE II. Ejection Test Conditions With Externally Applied Force.

SERIES NO.	TEST NO.	EJECTOR STROKE (in.) FWD	AFT	GN_2 PRESSURE (psig)	EXTERNAL FORCE (lbs)
4	3	6.0	6.0	3000	427
5	3	6.0	6.0	3000	853
7	3	4.5	6.0	3000	427
8	3	4.5	6.0	3000	853

Parallel Ejection

The first tests with externally applied force were conducted with the stroke lengths of the ejector assemblies equal. Figure 6 illustrates the CG location and the points of force application on the Mk 82 bomb. Two values of force were applied to simulate a nose down moment of 16,000 and 32,000 in-lbs. These moments were simulated with the application of a 427 lb load for 16,000 in-lbs and 853 lb for 32,000 in-lbs. It was predicted the ejector should be able to maintain a parallel store attitude up to 32,000 in-lbs moment nose down on the weapon. A graph of the distribution of ejector chamber pressures for 16,000 in./lbs nose down moment is shown on Figure 17 and for 32,000 in./lbs on Figure 18. The

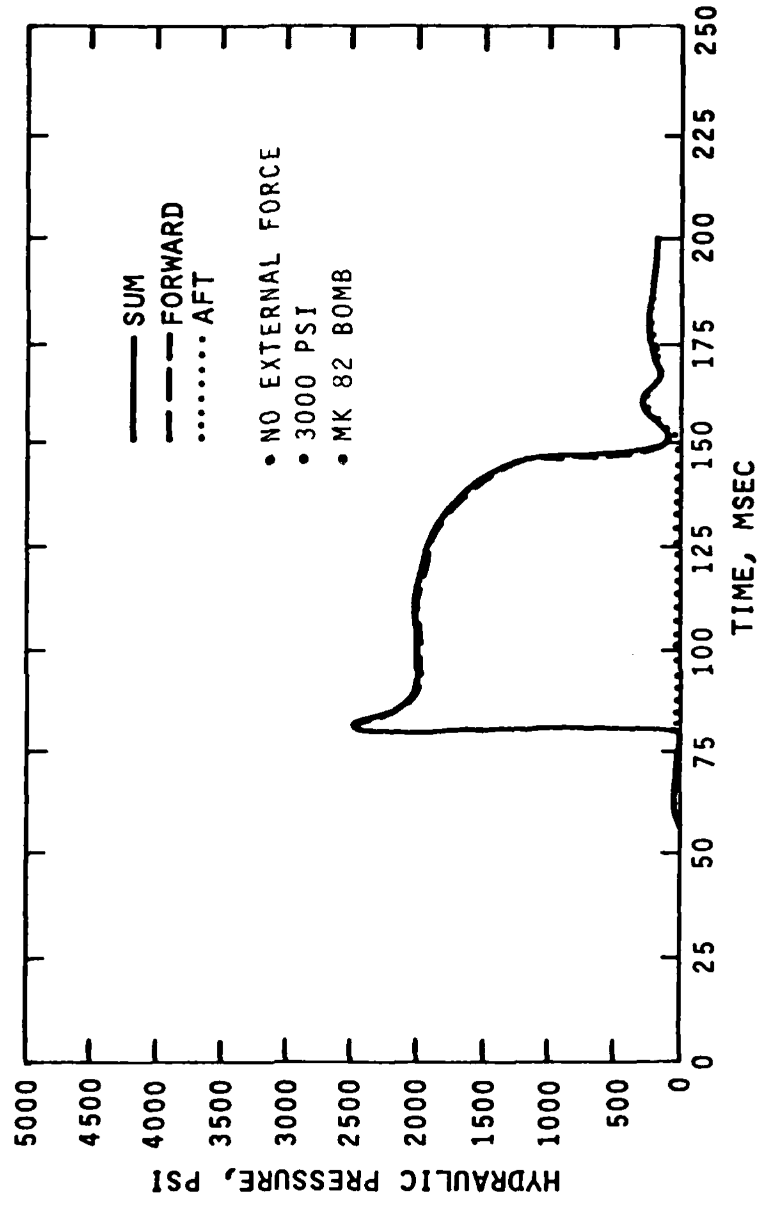


Figure 14. Forward and Aft Ejector Pressure Summation - 6/3 In. Strokes.

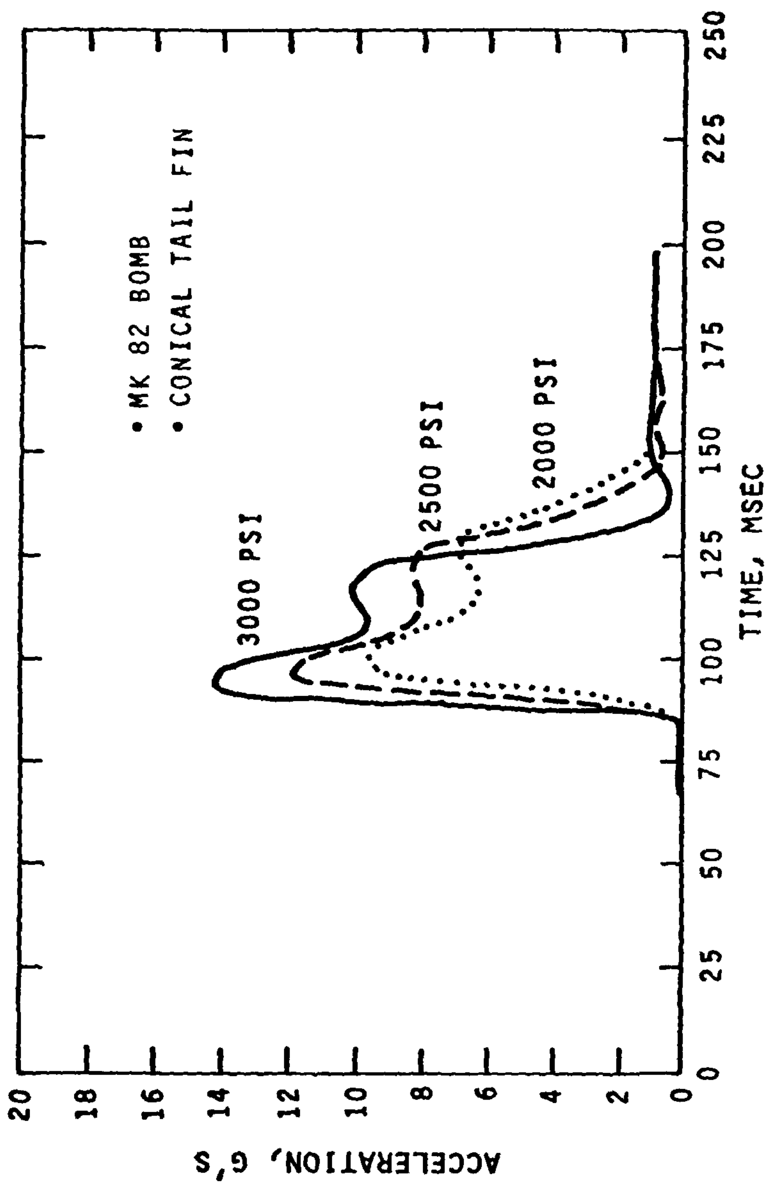


Figure 15. Ejection Acceleration.

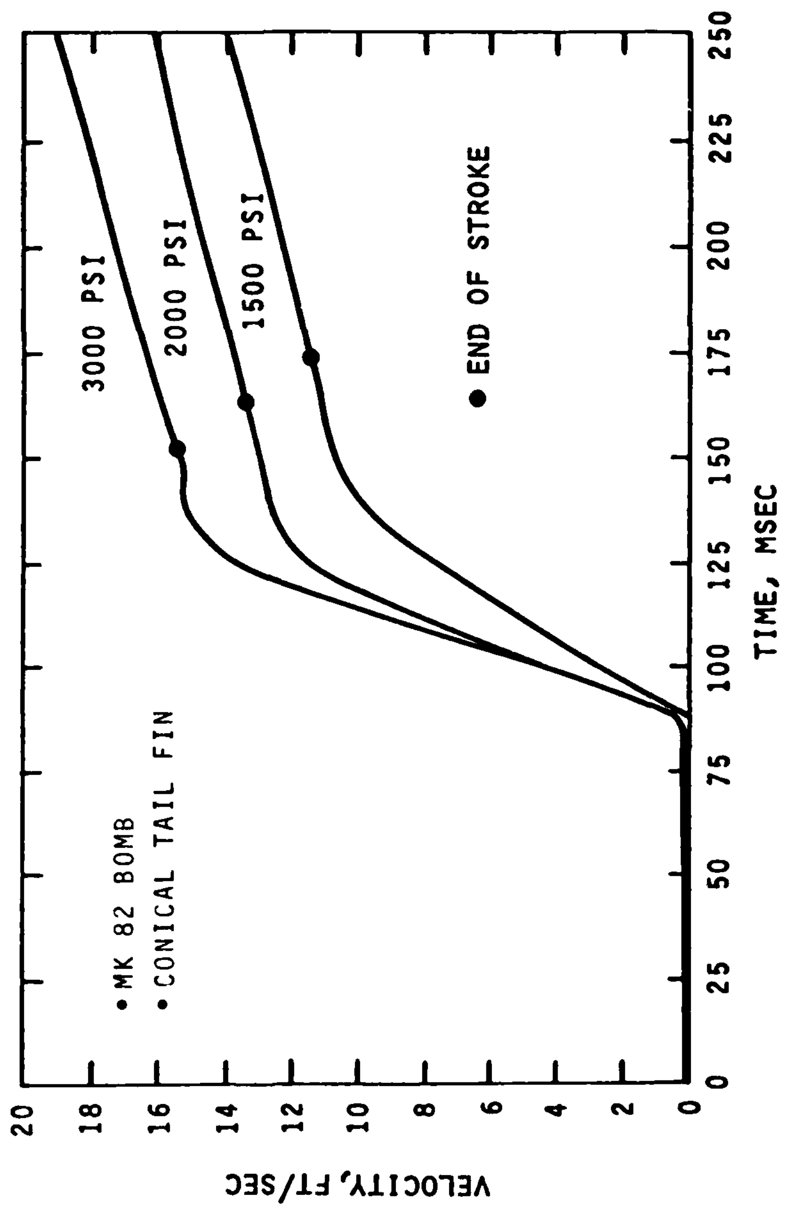


Figure 16. Ejection Velocity.

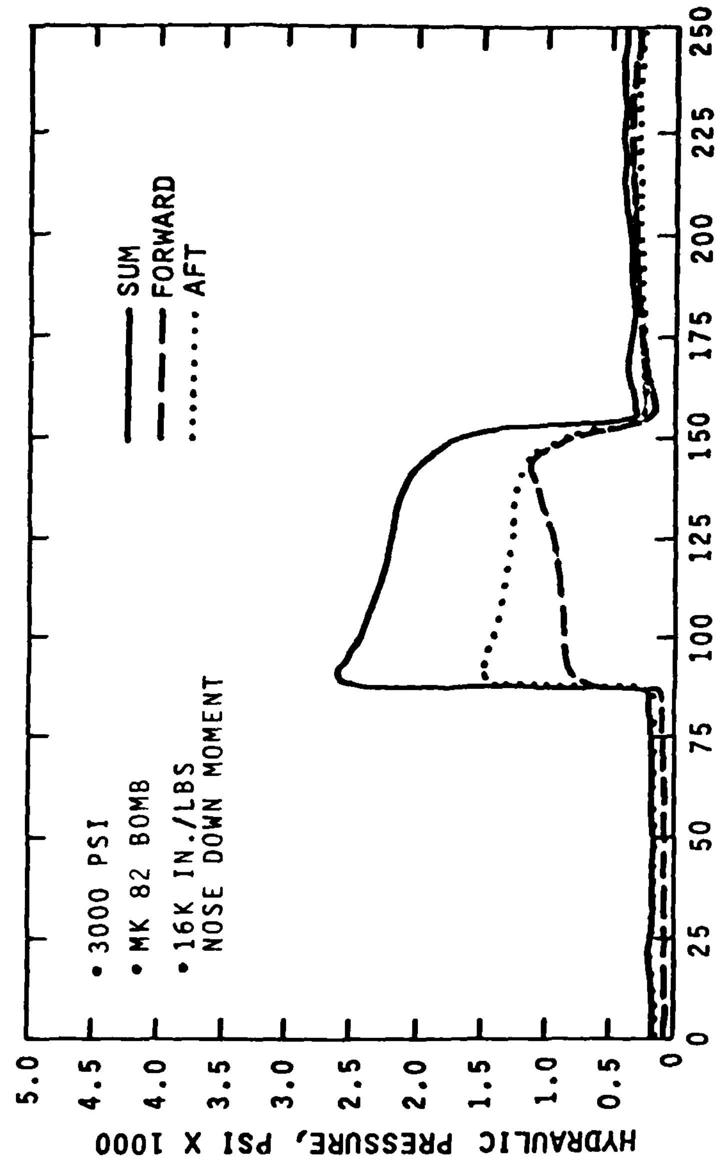


Figure 17. Forward and Aft Ejector Pressure Summation - 6/6 In. Strokes, with External Force.

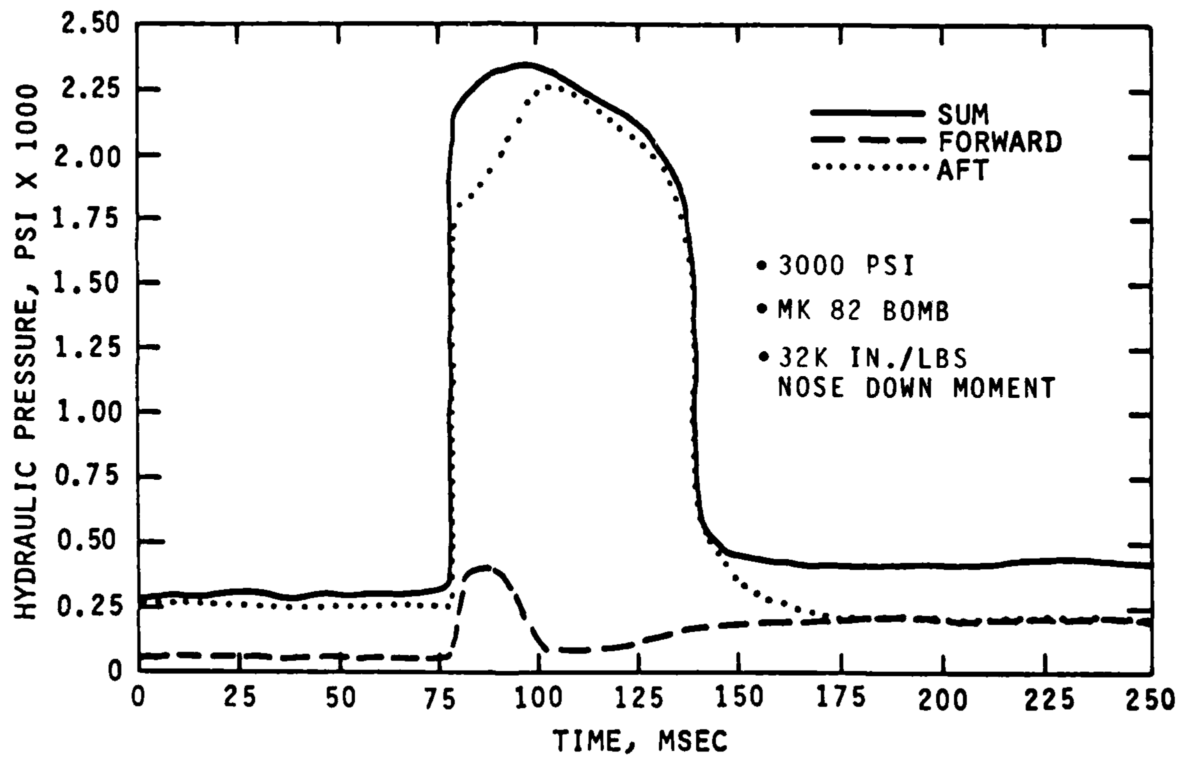


Figure 18. Forward and Aft Ejector Pressure Summation - 6/6 In. Strokes, with External Force.

total (sum of) pressure curves are the same for all ejections at 3000 psi. The pressure curves of the forward and aft piston assemblies (on Figure 17 and 18) show the automatic distribution of pressure to balance the external force. As more and more force is applied, the pressure is distributed to the aft piston until all the pressure is at the aft assembly with the 853 lb load applied.

Non-Parallel Ejection

The remainder of the tests were performed with stroke changes induced. The aft piston stroke was held constant at 6.0 inches while the forward piston assembly was reduced to 4.5 inches. The same external force was applied, as in the parallel ejection tests, to determine the effect on ejection performance. Figures 19 and 20 contain graphs of the pressure curves for 16,000 and 32,000 in./lbs applied nose down moment, respectively, showing the change in the forward and aft piston pressures while the total (sum of) pressure curves of each remain the same. The ejector system automatically compensates for the external load by balancing the pressures required for controlled ejection. Test data showed an attitude control capability of the test hardware of up to 32,000 in./lbs nose down moment at a GN_2 pressure of 3000 psi.

Acceleration and Velocity During Ejection

Acceleration and velocity data for the 3000 psi tests (with externally applied loads) are contained in Appendix C, Figures C-1 through C-4. The acceleration and velocity data were obtained from the recorded acceleration of the forward and aft accelerometers on the bomb.

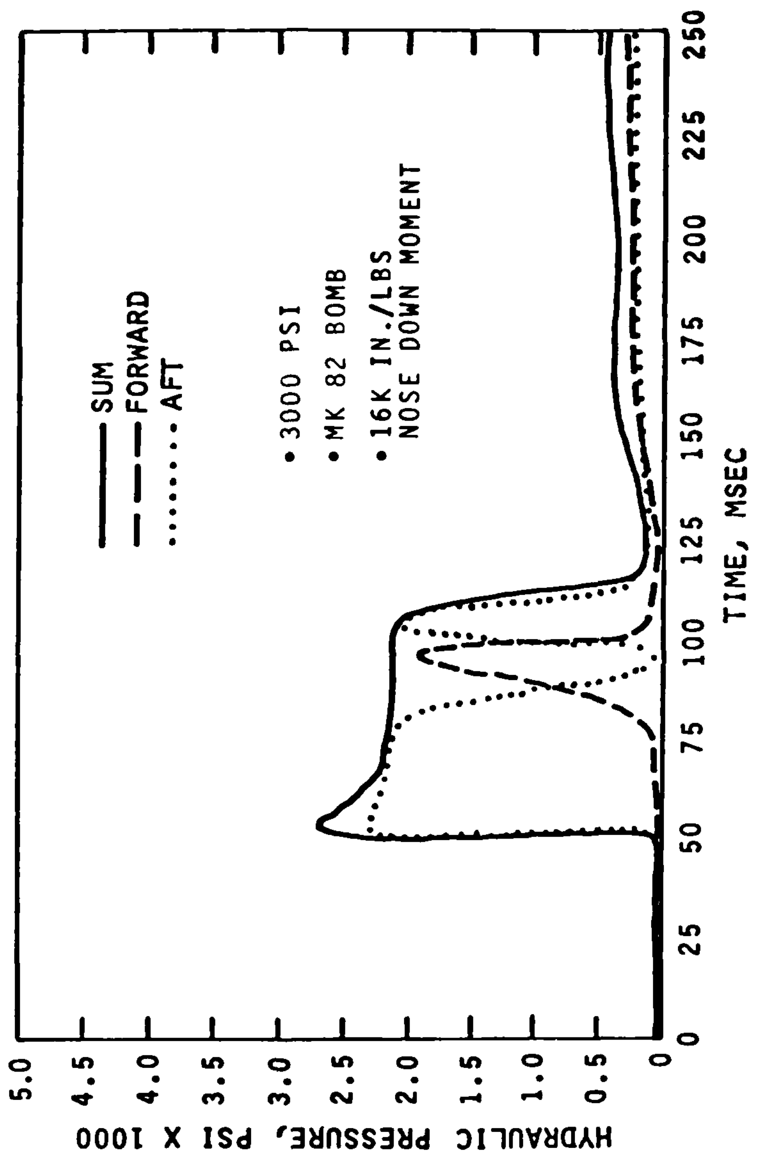


Figure 19. Forward and Aft Ejector Pressure Summation - 4.5/6 In. Strokes, with External Force.

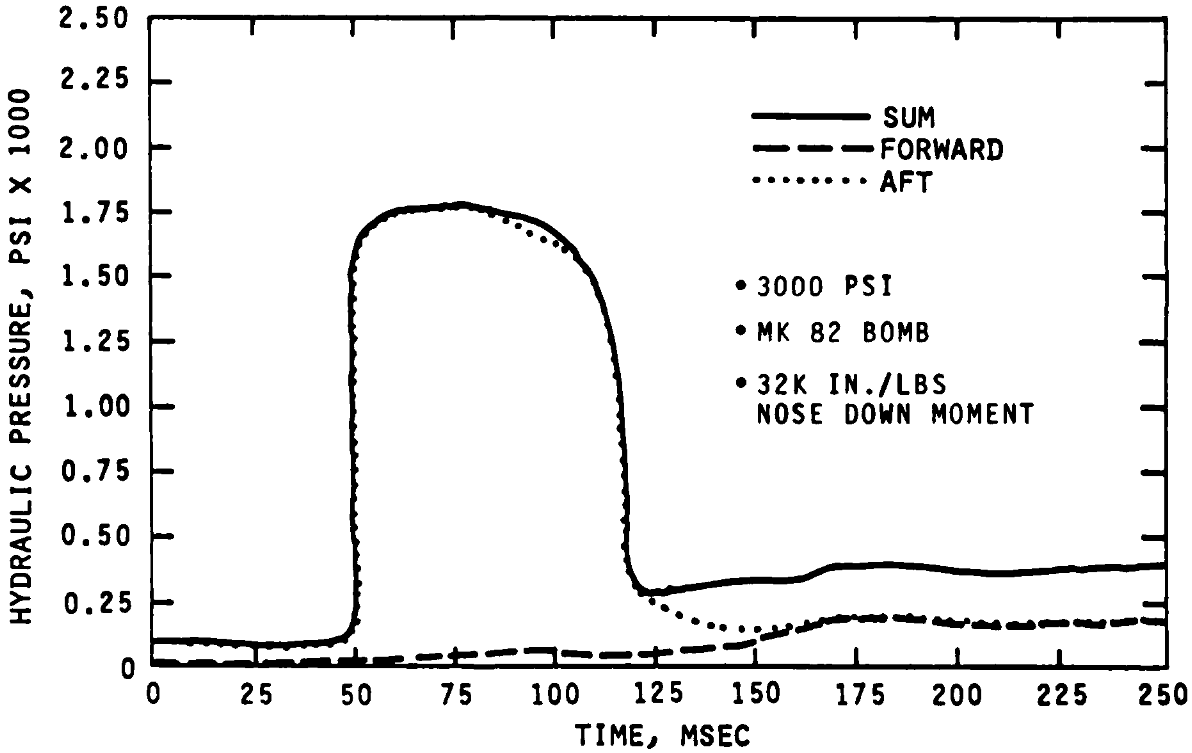


Figure 20. Forward and Aft Ejector Pressure Summation - 4.5/6 In. Strokes, with External Force.

SUMMARY AND CONCLUSIONS

The results of these first tests indicate the ejector system has the capability to provide parallel dependent ejection and to control the store in the pitch plane during the ejection cycle. With increased aircraft speeds, and the possible requirement for supersonic release of stores, it becomes apparent that pitch control of stores must be maintained throughout the ejection cycle. An ejector system with pitch control will expand the current release envelopes and still ensure safe separation of the weapon systems providing better compatibility with the performance of existing aircraft and the future generation of advanced aircraft. The use of hydraulics allows for flexibility in design of the ejector stroke length without significant increases in width, height or weight of the bomb rack. Current designs allow an ejector piston stroke extension of up to 11 inches. The capability of increased ejection stroke lengths and cold gas power systems will give more uniform store accelerations and will result in higher end of stroke velocities. The dependency characteristics will assure pitch control of the store throughout the ejection stroke. Given the requirement for ejection with changes in the pitch plane of the store, the ejector controls allow for pitch attitude change at end of stroke without pitch rate, or ejection of the store with induced pitch angular rate.

Ejector systems of this type will control the store pitch attitude independent of flow field forces and moments. Therefore, during the ejection stroke, the flow field forces are ineffective in perturbing the store in the pitch plane. The determination of the magnitudes and directions of these flow field forces throughout the aircraft flight envelopes is of major importance in enabling an adequate design of the ejector power system to balance these forces.

An added potential for this ejector system is the capability to measure ejector pressures (and thus, force/time) in each ejector assembly during ejection of the store. To date, the ability to determine what force, or forces are required to maintain the store parallel during ejection has not been demonstrated. This capability to measure the pressures as a function of time should be a useful tool to the aerodynamicist in analysing flow field phenomena for a better understanding of the forces acting on the store during ejection.

By use of a cold gas power system the capability exists to control store ejection velocities by varying the ejection pressures as required for safe separation. This could be an automatic feature built into the aircraft fire control system. A pressure sensor and control valve could be used to reduce the ejection pressure so safe separation of the store could be maintained. For example, a fully loaded MER would be ejected with maximum ejector pressure. As stores are released, the primary ejection pressure would be adjusted to match the existing load on the MER until such time as the MER is empty. The adjusted pressure would be the correct ejection pressure for an empty MER rack. This automatic capability would allow ejection of various stores from the same ejector with the correct pressure for better ballistic separation.

Ultimately, a complete set of release parameters for each store could be stored within the aircraft computer. With the integration of the aircraft sensors to indicate status at any time during flight, the ejector stroke and ejection controls could be set automatically to match the release environment present at that instant.

The use of a cold gas power system is highly recommended and should reduce the overall maintenance requirements to depot level only. A cold gas system will eliminate or reduce the following problem areas of ejection systems currently in use:

1. Aeroelastic problems during ejection through the capability to adjust the ejection forces to match the store.

2. CAD radiation hazards in the aircraft/store environment.

3. Removal, replacement, cleaning requirements and performance variability of CADs.

Current and projected FY76/77 activities are to design flight weight hardware for environmental and operational testing. Future considerations are for self-contained cold gas power systems which utilize the aircraft hydraulic/pneumatic systems to recycle the ejector system to the pressurized condition after store release. A complete system design integrates other advanced armament elements such as stores management system, data and power interface system, automated sway bracing, and automated stores and station identification system.

APPENDIX A

Appendix A contains a graphic presentation of simulated air loads (Figure A-1), showing applied moment and force, on a typical Mk 82 bomb which were externally induced for these tests. Also contained herein is a list of aircraft currently using Greene Tweed seals (TABLE A-I) and a complete listing of the dual ejector system test conditions (TABLE A-II).

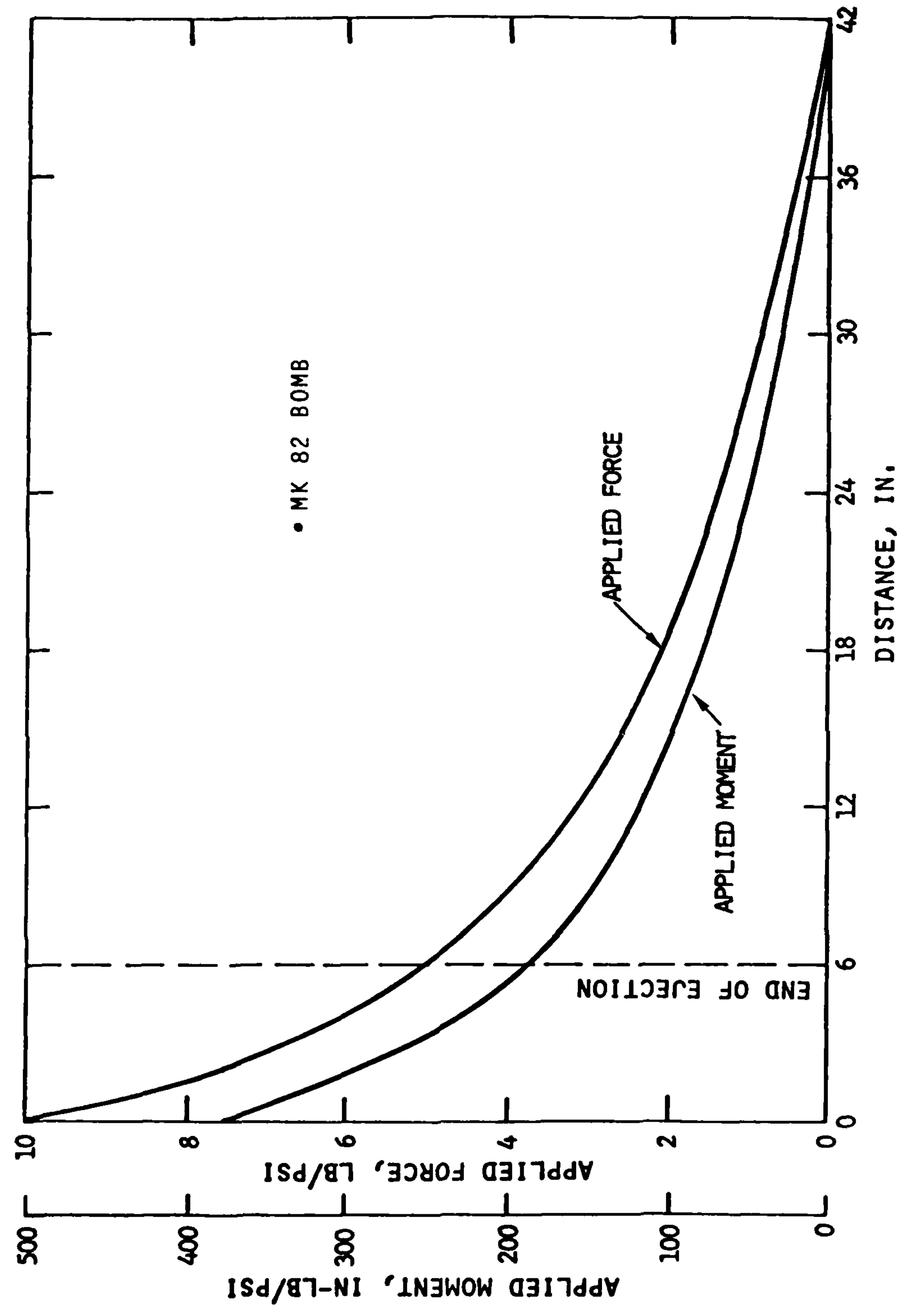


Figure A-1. Simulated Air Loads.

Aircraft currently utilizing Greene Tweed Seals in landing gear shock strut systems are listed in Table A-I.

TABLE A-I. Aircraft Utilizing Greene Tweed Seals.

CIVIL

(Delivered by the manufacturer with Greene Tweed Seals.)

Boeing 727	Douglas DC-8	Lockheed L-1011
Boeing 737	Douglas DC-9	Concorde
Boeing 747	Douglas DC-10	A-300
		Mercure

MILITARY

A-7	C-5A	CH-3	F-4	T-2
A-10	C-7A	CH-53	F-8	T-38
A-37	C-123	CH-46	F-5	B-66
	C-130		F-14	S-3A
	KC-135		F-15	
	C-141		F-102	
	C-118		F-105	
			F-111	

Development Stage Military Aircraft

B-1
YF-16
YF-17
UTTAS and HLH helicopters

TABLE A-II. Dual Ejector Test Conditions

SERIES NO.	TEST NO.	EJECTION PRESSURE INITIAL	INCREMENT	FINAL	EJECTION STROKE FWD	AFT	FORCE	MOMENT
I	1-9	1000	250	3000	6.00	6.00	0	0
II	1-9	1000	250	3000	6.00	4.54	0	0
III	1-3	2000	500	3000	6.00	3.07	0	0
IV	1-3	2000	500	3000	6.00	6.00	427	-16K
V	1-3	2000	500	3000	6.00	6.00	853	-32K
VI	1-2	2500	500	3000	6.00	6.00	1280	-48K
VII	1-3	2000	500	3000	4.54	6.00	427	-16K
VIII	1-3	2000	500	3000	4.54	6.00	853	-32K
IX	1-2	2500	500	3000	4.54	6.00	1280	-48K
X	1-2	2500	500	3000	3.06	6.00	853	-32K
XI	1-2	2500	500	3000	3.06	6.00	1280	-48K

APPENDIX B

Appendix B contains acceleration and velocity curves (Figures B-1, B-2 and B-3) for 3000 psi ejection pressures with no external forces applied to the Mk 82 bomb. Acceleration and velocity data for ejector stroke lengths of 6.0 in. forward/6.0 in. aft, 6.0 in. forward/4.5 in. aft, and 6.0 in. forward/3.0 in. aft, respectively, are contained in these figures.

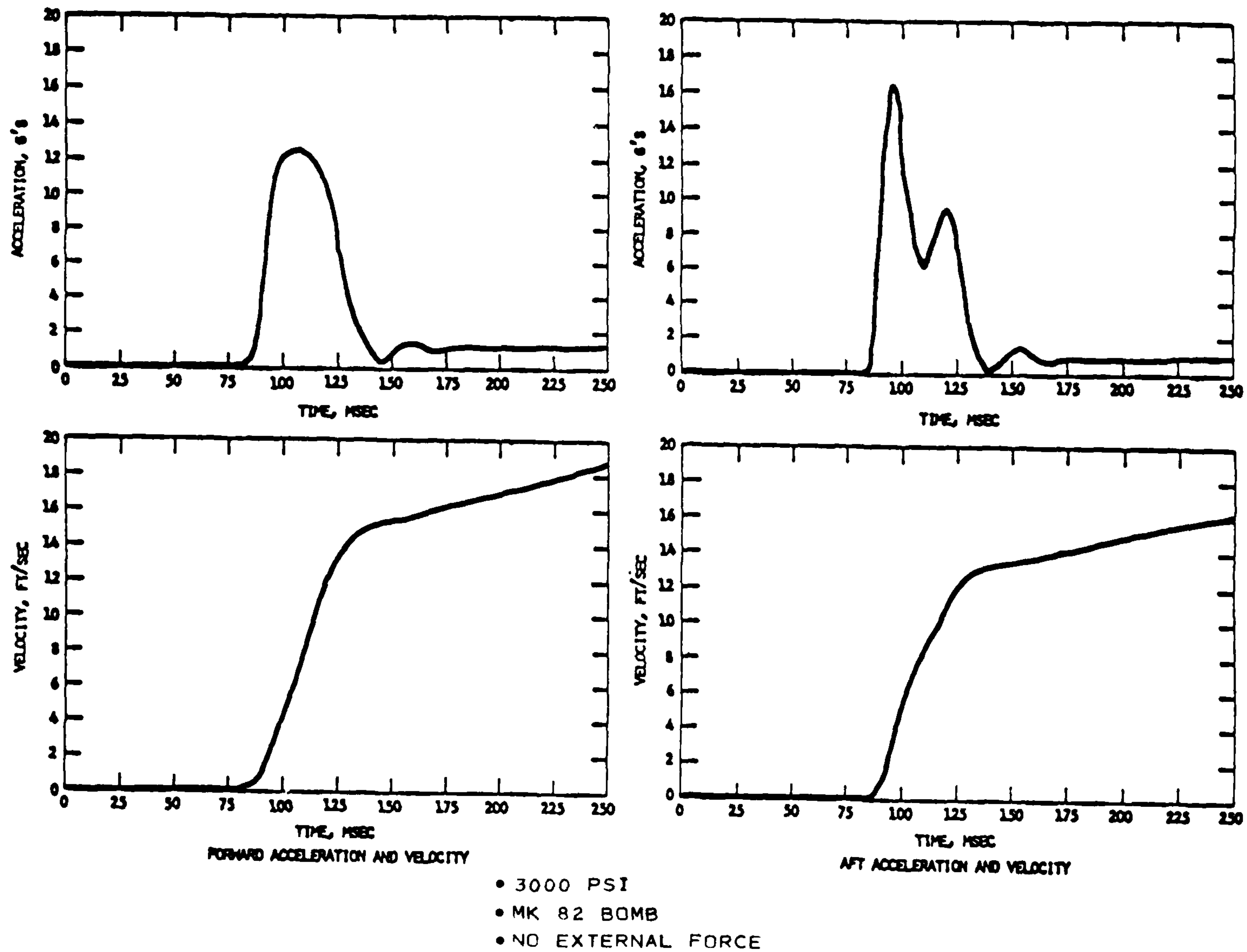
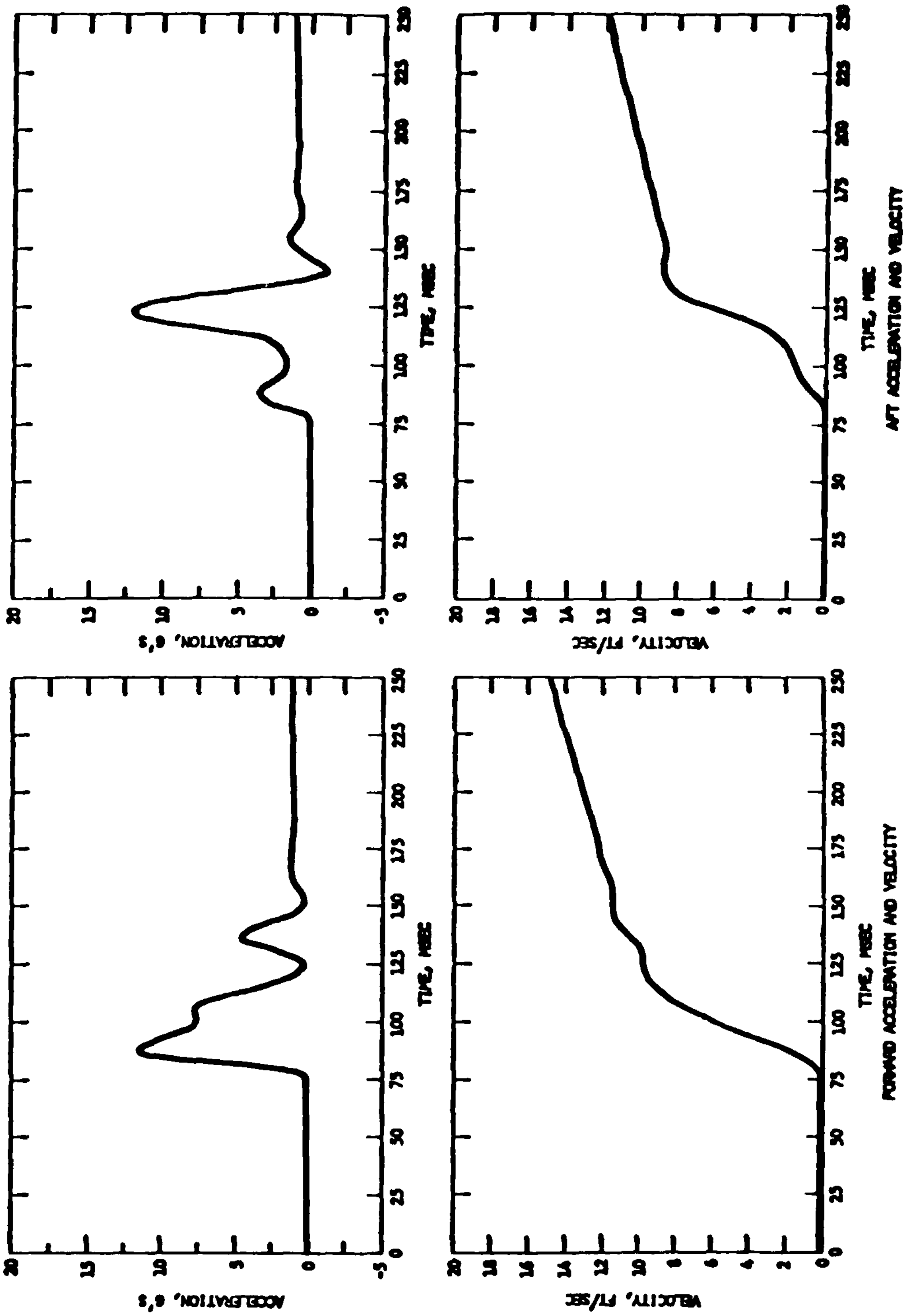


Figure B-1. Acceleration and Velocity - 6/6 In. Strokes.



- 3000 PSI
- MK 82 BOMB
- NO EXTERNAL FORCE

Figure B-2. Acceleration and Velocity - 6/4.5 In. Strokes.

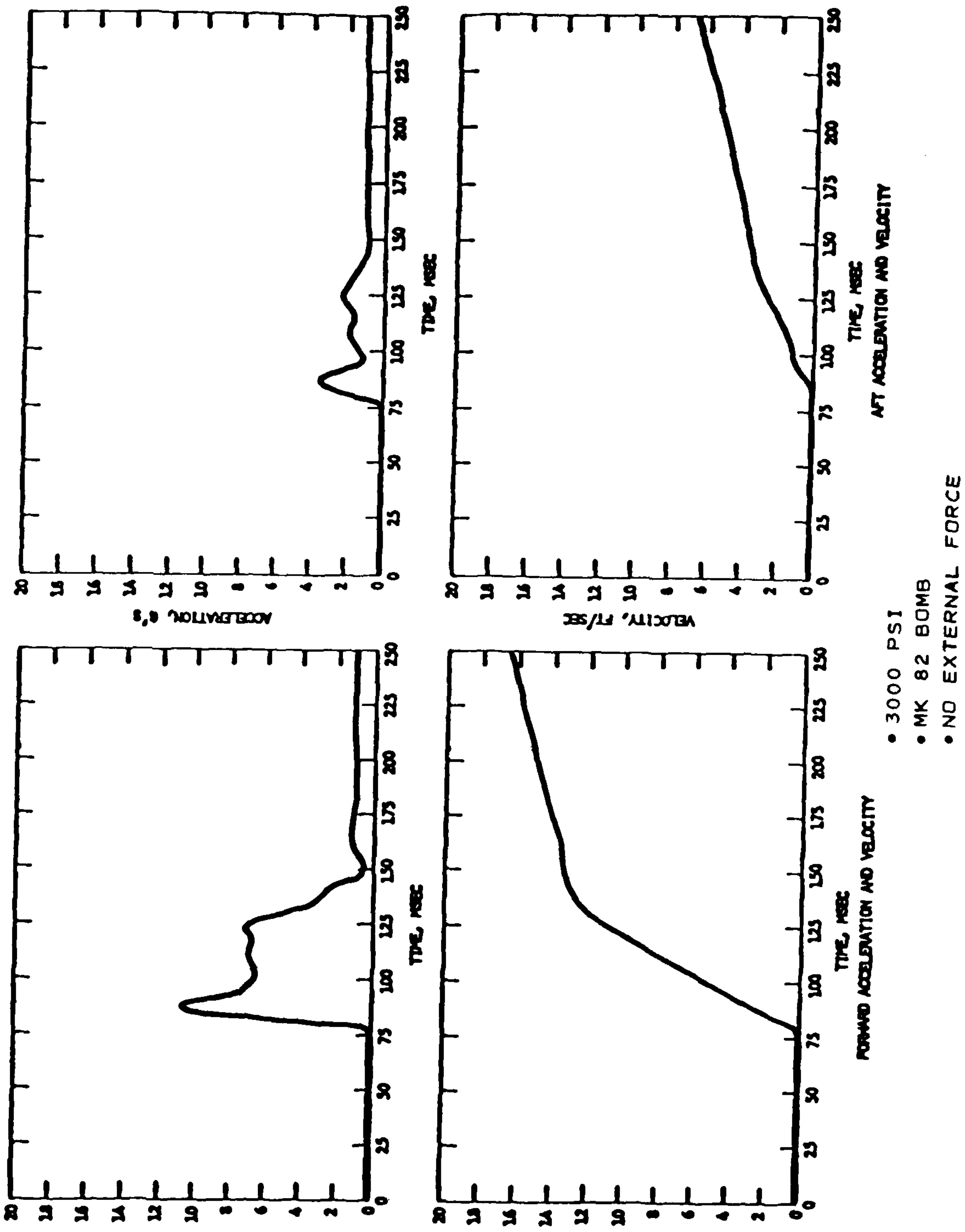
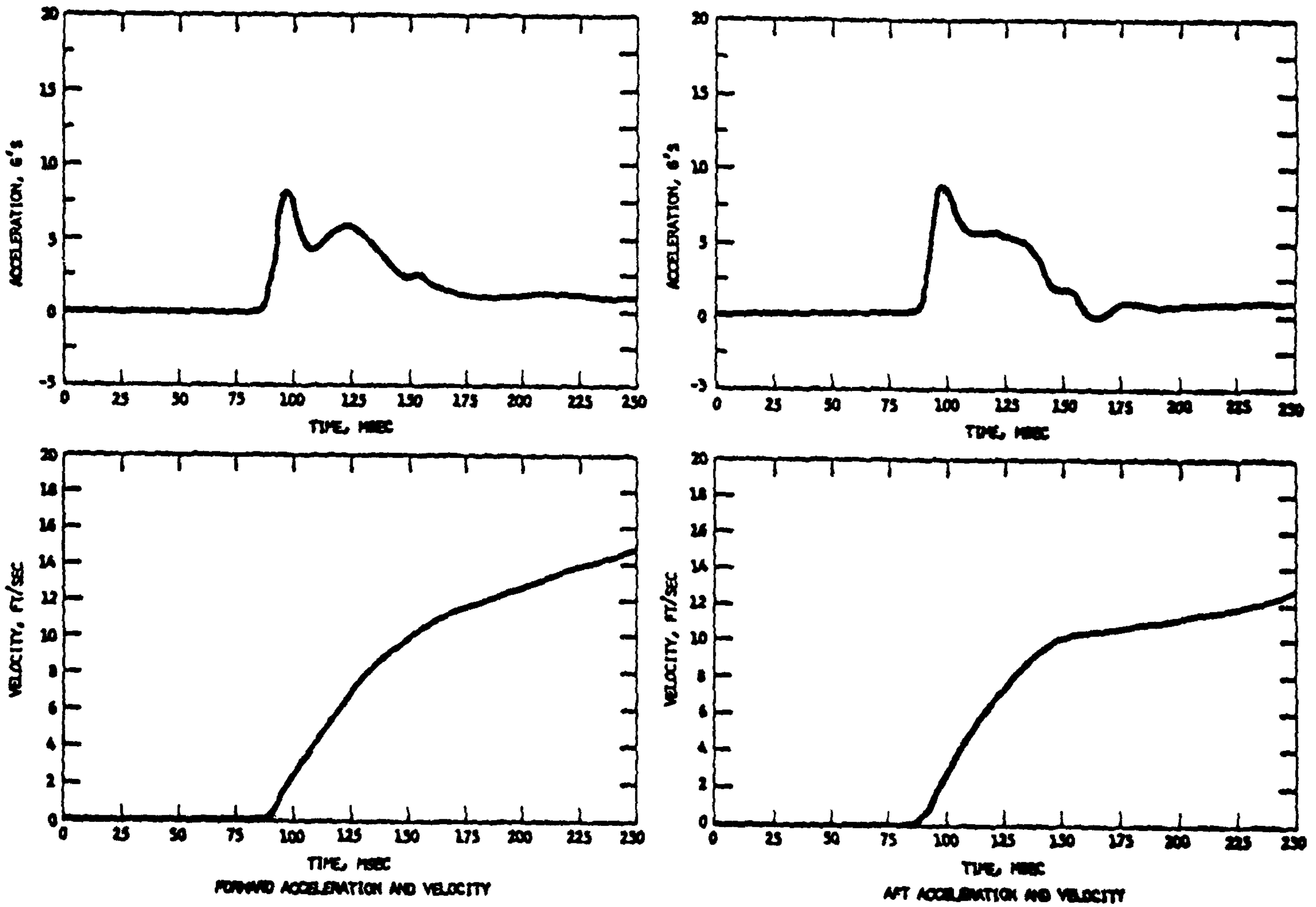


Figure B-3. Acceleration and Velocity - 6/3 In. Strokes.

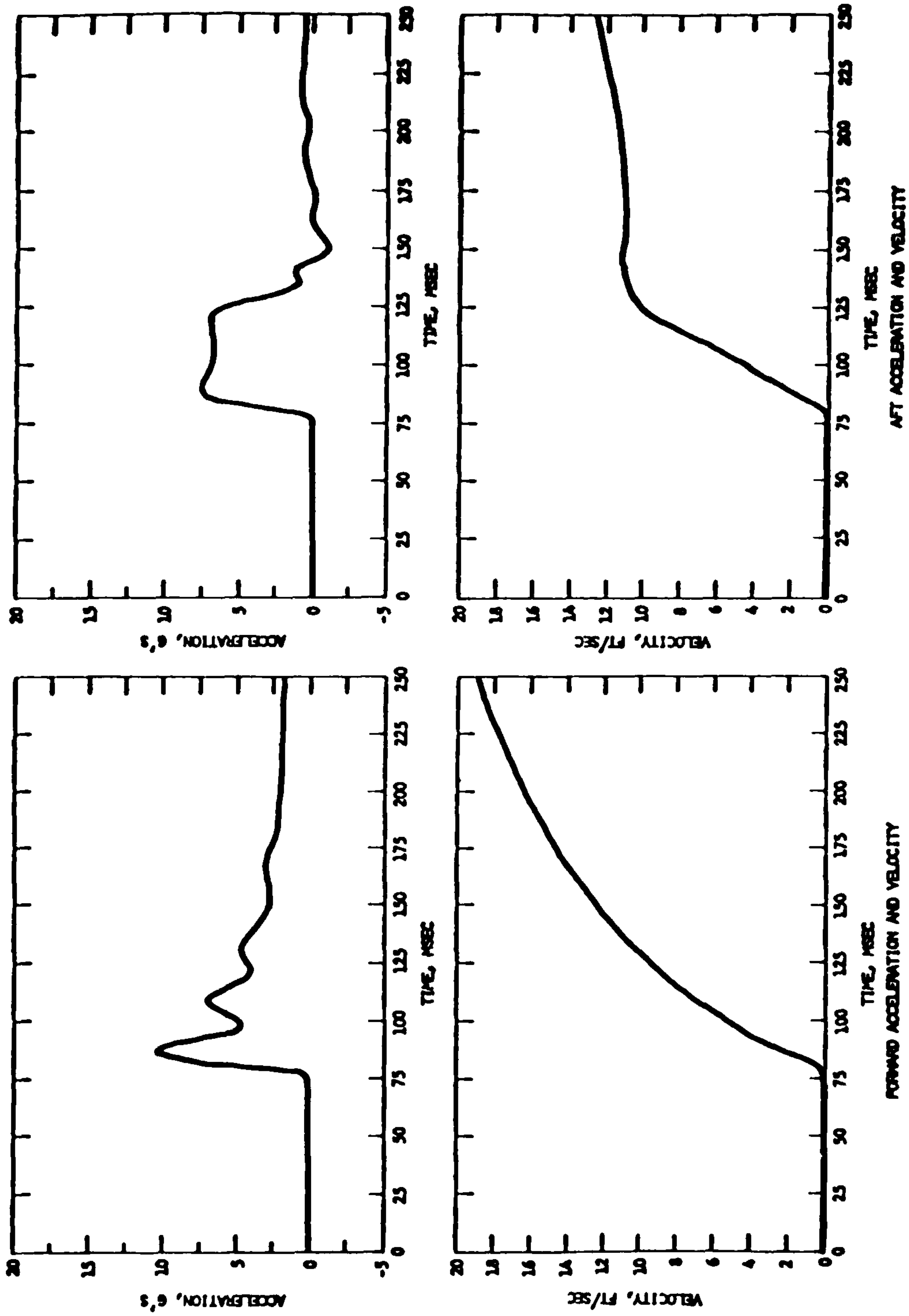
APPENDIX C

Appendix C contains acceleration and velocity curves (Figures C-1 thru C-4) for 3000 psi ejection pressures with external simulated air loads applied to the Mk 82 bomb. Acceleration and velocity data for ejector stroke lengths of 6.0 in. forward/6.0 in. aft and 4.5 in. forward/6.0 in. aft, respectively, with externally applied nose down moment of 16,000 and 32,000 in./lbs are contained in these figures.



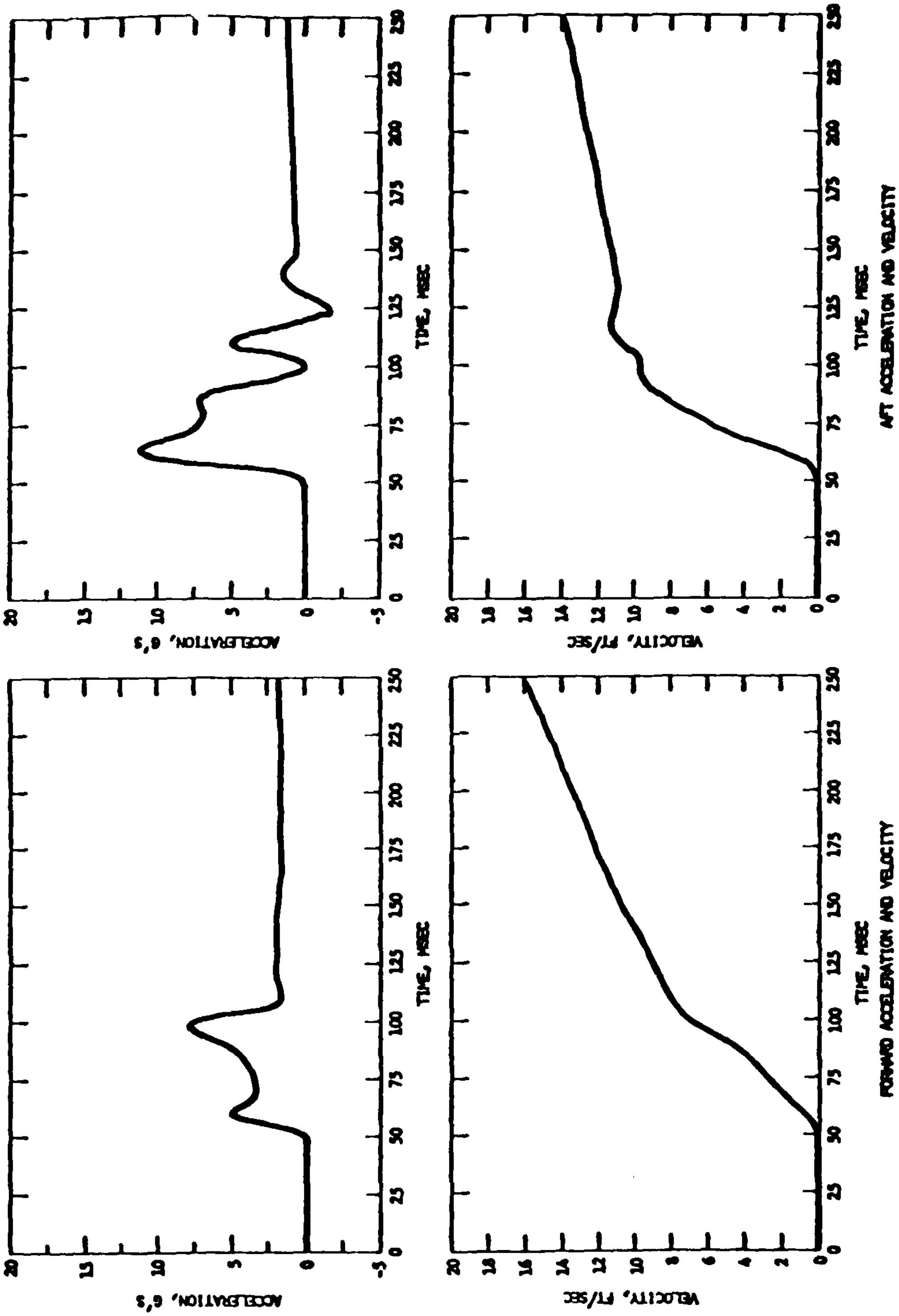
- 3000 PSI
- MK 82 BOMB
- 16K IN./LBS NOSE DOWN MOMENT

Figure C-1. Acceleration and Velocity - 6/6 In. Strokes, with External Force.



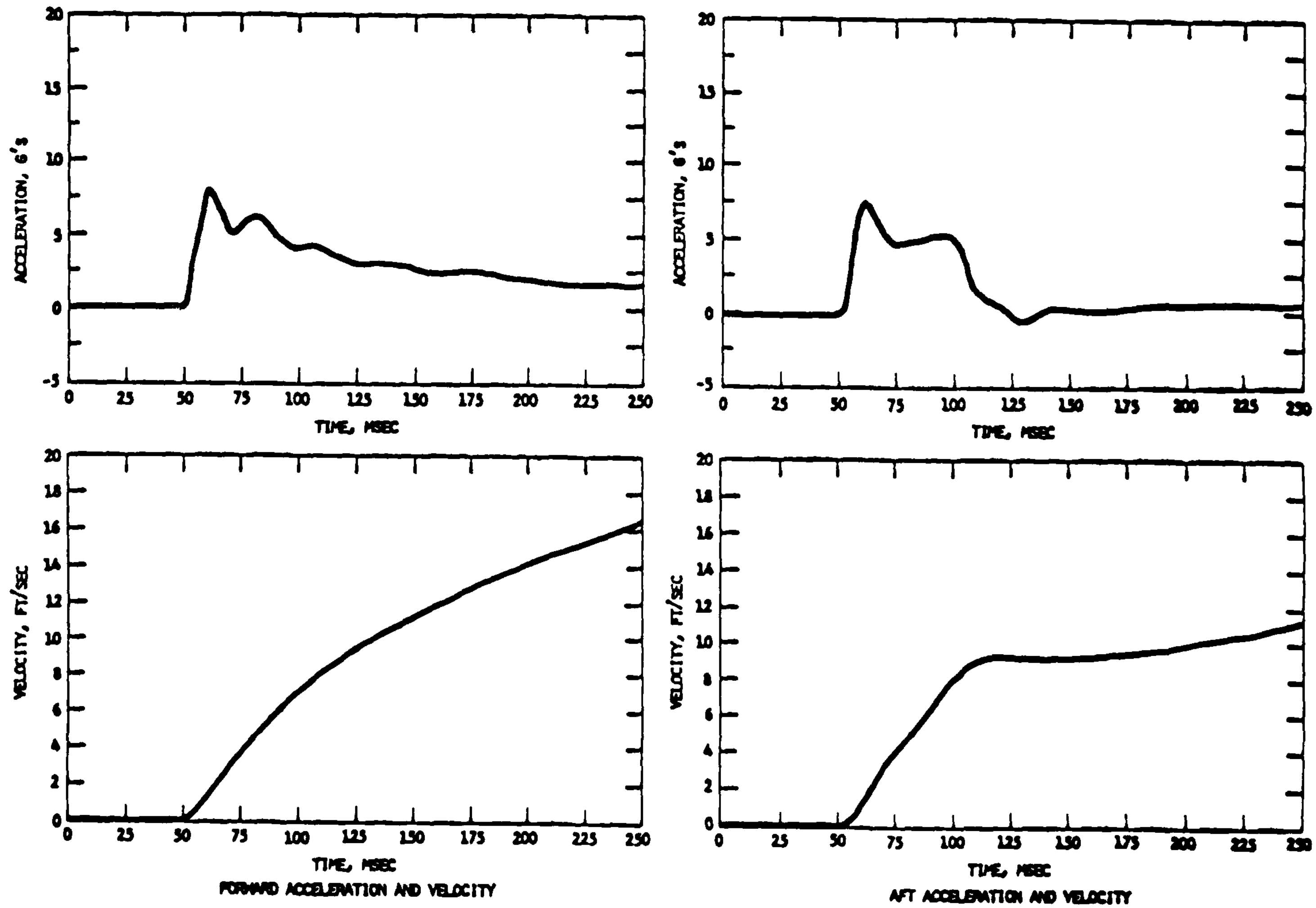
- 3000 PSI
- MK 82 BOMB
- 32K IN./LBS NOSE DOWN MOMENT

Figure C-2. Acceleration and Velocity - 6/6 In. Strokes, with External Force.



- 3000 PSI
- MK 82 BOMB
- 16K IN./LBS NOSE DOWN MOMENT

Figure C-3. Acceleration and Velocity - 4.5/6 In. Strokes, with External Force.



• 3000 PSI
• MK 82 BOMB
• 32K IN./LBS NOSE DOWN MOMENT

Figure C-4. Accel_ration and Velocity - 4.5/6 In. Strokes, with External Force.

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